

University Of Alberta



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ALCHEM

Elective Teachers' Guide

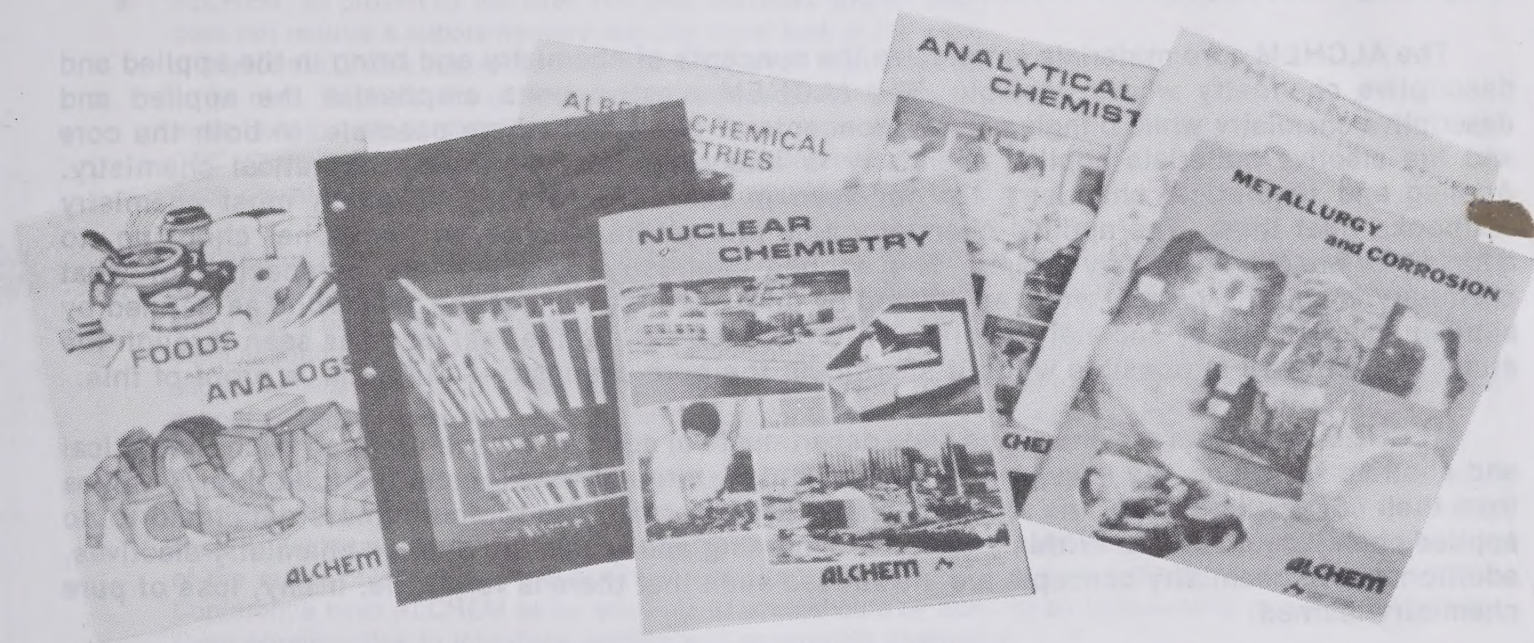


Table of Contents

Analytical Chemistry - Unit J

Foods and Their Analogs - Unit O

Ethylene and its Derivatives - Unit P

The Athabasca Tar Sands

Metallurgy and Corrosion - Unit T

Nuclear Chemistry - Unit U

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INTRODUCTION

Preliminary Edition

The ALCHEM Electives Teachers' Guide has been delayed in printing because of the greater emphasis that we place on the student materials and because of the regular revision of the electives. We like to be into the second or third (preferably the third) edition of an elective before it is published. Most of the electives have been published in their second edition form because of the lack of the elective material available to chemistry teachers. The Electives Teachers' Guide is being published in preliminary form in order to encourage teachers to use applied electives such as ours. Applied chemistry electives can initially be scary to teach because of the lack of university training and reference materials in these areas, but student enthusiasm will soon reward a decision to take the risk.

Integrating Pure, Applied and Societal Chemistry

The ALCHEM core materials emphasize the concepts of chemistry and bring in the applied and descriptive chemistry where possible. The ALCHEM elective units emphasize the applied and descriptive chemistry while bringing in the concepts of chemistry where possible. In both the core and the elective materials applied chemistry is integrated with rigorous, theoretical chemistry. Applied and theoretical chemistry are not seen in the either/or way in which most chemistry textbooks treat them. The applied chemistry also allows the teacher, at his or her choosing, to address science and society issues. The applied chemistry broadens the perspective of what chemistry is about. The *real world* as defined by pure chemistry is not the *real world* as defined by applied chemistry or by societal chemistry. A broadened view of the *real world* as seen through the study of chemistry is possible without sacrificing the pure chemistry—ALCHEM is proof of this.

ALCHEM and some provincial and state departments of education have dropped such theoretical and abstract topics as gas laws, quantum mechanics, rates of reactions and equilibrium K-values from their core outline. The time saved has been used to treat less topics in more detail and to do applied chemistry electives. Within the topics remaining and within the applied chemistry electives, additional pure chemistry concepts are introduced such that there is very little, if any, loss of pure chemistry learned.

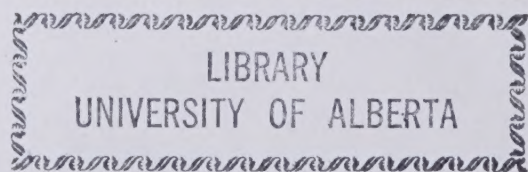
In a time when science and society are so closely associated, it is not longer suitable to have the "top" science students learn only the pure chemistry and the "less able" students learn only the applied and societal chemistry. The "top" science students need to know of the societal problems associated with science and the "less able" students are more capable than given credit for (especially when they see some application to *their real world*).

Future Developments

ALCHEM will be piloting some new electives in the near future and will continue to revise the current core materials and electives. The *worktext* format of the electives allows for revisions and for either the purchase or rental of the materials by the students. Our challenge is to make the context important enough to be worth purchasing and keeping as a home reference. Your comments based on classroom interactions and on reflections outside the classroom would be of great assistance. Write to us.

Note:

Alberta Chemical Industries is only in preliminary form and will be "finalized" in the spring of 1981. The Teachers' Guide for this elective will be distributed at that time.



How to Use the ALCHEM Materials

1. The ALCHEM materials were written to provide maximum flexibility of teaching styles. No particular teaching method is intended. The teaching method used should depend on the skills and abilities of the teacher and the students. Some teachers send students to the blackboard, some teachers use an overhead projector, some teachers go over difficulties on the blackboard and some teachers provide individual assistance. Probably a variety of approaches, depending on the situation, would be best. Most teachers, however, follow a pattern of a. take up last days' homework, b. introduce a new concept, and c. provide some classroom time to start the homework assignment.
2. ALCHEM is not intended to provide 100 % of the materials for "independent", "self" or "individual" study. Probably about 80 % of the material for such a program is provided by ALCHEM. The ALCHEM materials are intended for the majority of classrooms where the students proceed at the "same rate" (the slower students needing more homework time). Independent study should only be used by teachers who are trained and committed to the approach (and are willing to put in the extra time and effort required). ALCHEM is not an independent study course.
3. ALCHEM, as proven by the over 100 pilot teachers and 40 000 to 50 000 students, is self-contained and does not require a supplementary text. An initial look at the materials might lead to a conclusion (because of the format) that a supplementary text is required. Four years of piloting have shown that ALCHEM stands on its own. Page counts of textual material in ALCHEM versus competing texts show that ALCHEM has more textual material than its competitors. The only recommended supplement is a reference such as the CRC (Chemical Rubber Company) Handbook of Chemistry and Physics. One CRC Handbook should be in each classroom - especially for questions arising in ALCHEM 20 and 30.
4. The applied chemistry provided in the background to the textual material, exercises, demos and labs is not intended as testable material. The applied chemistry is there for the student to read and hopefully come away with a better idea of the usefulness and importance of chemistry to many facets of life. There is sufficient applied chemistry provided so that the teacher can choose his time and place to expand on whatever aspect he wishes. It is intended that the applied chemistry be used to meet the "other objectives" of high school chemistry (see the new Alberta Education Chemistry Curriculum Guide).
5. The International Conference on New Directions in Chemistry Curriculum (1978) at McMaster University in Hamilton, Ontario concluded with one major recommendation - more applied and descriptive chemistry should be integrated into the chemistry curriculum, at the expense of abstract principles. This has been one of the major objectives of the ALCHEM materials since their beginning in 1973. Many speakers at the Conference used ALCHEM as an example of what should be done by all textbooks to provide many classroom opportunities to introduce applied and descriptive chemistry.
6. The labs were written to be single concept labs and to provide the necessary experiences to assist students with the theory and language of chemistry. Labs constitute greater than 25 % of classroom time and are very important to the conceptualization of the abstract ideas presented in chemistry. The majority of the labs can be completed from either a "discover" or from a "verification" point of view - depending on the teacher's preference or the availability of the laboratory.
7. Most teachers employ closed-book exams and provide the students with an ALCHEM periodic table (and an ALCHEM data sheet in ALCHEM 30) for reference. Extra periodic tables and data sheets are available from the suppliers of ALCHEM material.

ALCHEM MATERIALS

ALCHEM 10 (168 pages)
ALCHEM 20 (206 pages)
ALCHEM 30 (216 pages)

Nuclear Chemistry (64 pages)
Analytical Chemistry (40 pages)
Foods and Their Analogs (64 pages)
Metallurgy and Corrosion (40 pages)
Ethylene and its Derivatives (48 pages)
Athabasca Tar Sands (40 pages)
Chemical Industries (48 pages)

ALCHEM 10 Teachers' Guide
ALCHEM 20 Teachers' Guide
ALCHEM 30 Teachers' Guide
ALCHEM Electives Teachers' Guide

ALCHEM 10 Test Item Bank
ALCHEM 20 Test Item Bank
ALCHEM 30 Test Item Bank
ALCHEM Periodic Table
ALCHEM Data Sheet
ALCHEM Periodic Wall Chart (Side 1 Elements)
ALCHEM Periodic Wall Chart (Side 2 Ions)
ALCHEM Data Wall Chart (Side 1)
ALCHEM Data Wall Chart (Side 2)

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Elective Table of Contents

Nuclear Chemistry

Part 1—Stability of Nuclei and Radioactivity, Part 2—Nuclear Reactions (Radioactive Decay, Artificial Transmutations, Fission and Fusion, and Stellar Reactions), Part 3—Energy Changes ($E = \Delta mc^2$), Part 4—Nuclear Reactors (how they work), and Part 5—Applications of Nuclear Reactors (power generation, research, production of radioisotopes for industry, agriculture and medicine, and production of nuclear fuels). No prerequisite.

Analytical Chemistry

The unit is primarily four analytical labs—two qualitative analysis and two quantitative analysis labs. Cation analysis and anion analysis labs are followed by a gravimetric analysis for copper and a volumetric analysis for ASA. Prerequisite: Solution chemistry.

Foods and Their Analogs

The structure, digestion, respiration and synthesis of lipids (fats), proteins and carbohydrates are covered along with some man-made derivatives (soap), functional analogs (detergents, synthetic sweeteners) and structural analogs (polyesters, cellulose polymers and nylon) of these three food substances. Labs on the production of soap and cellulose acetate and demos on the production of polyesters and nylon are included. Prerequisite: Organic chemistry.

Metallurgy and Corrosion

Part 1 deals with the conversion of the ore into the pure metal by concentrating, roasting, reducing and refining. Part 2 concerns the corrosion of the metal back to its ore-like state. Three labs and two demos are part of the unit. Prerequisite: Electrochemistry.

Ethylene and Its Derivatives

An historical and current description of the production and uses of ethylene, polyethylene, polyvinyl chloride, ethylene glycol, ethanolamines and polyesters. Two labs—Identification of Polymers and Production of Polystyrene. Prerequisite: Organic chemistry.

The Athabasca Tar Sands

After describing the location, extent, composition and history of the Athabasca tar sands, the extraction and upgrading processes are followed through via a flowchart. The extraction of bitumen (including a lab) and the cracking of the bitumen (including a demo) is followed by the hydrotreating of the synthetic crude and the sulfur removal from the process gas. Prerequisite: Hydrocarbon chemistry.

Chemical Industries

This elective reinforces inorganic nomenclature, writing balanced chemical equations and doing gravimetric stoichiometry problems in the context of inorganic-based chemical industries. The products and processes of the industries are studied and the uses of the products are discussed. Prerequisite: Inorganic nomenclature, chemical equations and gravimetric stoichiometry.

ACKNOWLEDGEMENTS

The ALCHEM project is indebted to the ALCHEM pilot teachers and students; the Queen Elizabeth Composite High School administration (Walter Sharek and Florence Phillips), secretarial staff (Dorothy Bell), industrial arts department (Gerry Mikytyshyn), art department (Don Pasmore) and science department (Hans van Kessel and Bill Tanasichuk); the Edmonton Public School Board departments of Research and Evaluation, Pupil Assessment, and Purchasing and Stores (Don Witwicky); the University of Alberta departments of Chemistry and Secondary Science Education; the many Alberta chemical industries that supplied information and encouragement and to J.M. LeBel Enterprises for supporting our publishing concepts, to Sandra Wright for typesetting the books and to K.C. Conroy for her straight arrows. A special thanks goes to the families of the ALCHEMists for their patience and support.

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Analytical Chemistry

Table 1. Standardization of the Analytical System			
Sample	Concentration (mg/L)	Area (a.u.)	Response (a.u.)
A	10	1.2	1.2
B	20	2.4	2.4
C	30	3.6	3.6
D	40	4.8	4.8
E	50	6.0	6.0
F	60	7.2	7.2
G	70	8.4	8.4
H	80	9.6	9.6
I	90	10.8	10.8
J	100	12.0	12.0

General Information on Ion Analysis Labs

1. Cleanliness

Stress the importance of cleanliness. All glassware must be thoroughly washed and rinsed with running water. The final rinse or two *must* be with distilled (deionized) water. Accurate results will not be obtained if the distilled water rinse is eliminated.

2. Flame Tests

Students should be encouraged to clean the platinum (or nichrome) wire *thoroughly*. Demonstrate the procedure so students may see that it takes *several* flamings before the wire imparts *no color* to the flame. If using glass rods instruct students to not heat the glass or dip the glass in the hydrochloric acid cleansing solution (the glass will shatter). It would be useful to also demonstrate the flame test for $\text{Na}^+(\text{aq})$, $\text{Ca}^{2+}(\text{aq})$ and $\text{K}^+(\text{aq})$. These are the only ions in this lab that will give a noticeable flame color.

3. Plastic Thumb Protectors

Cut the plastic thumb protectors, 3 cm x 3 cm, out of sheets of polyethylene or Saran. Instruct students to discard the used one and to use a new one each time.

4. Preparation of Solutions

To prepare one litre of solution dissolve the given mass in enough distilled (deionized) water to make one litre of solution. Check the formula of the compound as listed on the reagent bottle. If different from the formula given below, a new mass will have to be calculated.

5. Student Solutions

Once the solutions have been prepared in the appropriate concentrations, they should be placed in clean, dry dropping bottles. One complete set of dropping bottles containing the reagents required for the lab may be placed in a box or aluminum tray and should be sufficient for two laboratory stations.

6. Unknown Solutions

The unknown solutions must be freshly prepared from the solids. Four unknowns can be made into 32 unknowns by assigning each of the four, eight different numbers as shown.

Unknown	Assigned Unknown Number							
A	1	7	12	15	20	23	25	32
B	2	6	11	13	17	21	26	31
C	3	8	9	14	19	24	27	30
D	4	5	10	16	18	22	28	29

7. Laboratory Safety

Several of the chemicals used may have adverse effects on skin or clothing. Care should be taken with *all* solutions and any spills should be cleaned up immediately. A clean and tidy lab bench helps to avoid many problems.

Lab J1—Pages J2-J10

1. Reagent Solutions

The following solutions (in dropping bottles) form a complete set of reagents for the cation analysis.

- 6 mol/L $\text{HCl}_{(\text{aq})}$
- 6 mol/L $\text{NH}_4\text{OH}_{(\text{aq})}$
- 6 mol/L $\text{HNO}_3_{(\text{aq})}$
- 6 mol/L $\text{NH}_4\text{Cl}_{(\text{aq})}$ (53.5 g/L of $\text{NH}_4\text{Cl}_{(\text{s})}$)
- 6 mol/L $\text{NaOH}_{(\text{aq})}$ (240 g/L of $\text{NaOH}_{(\text{s})}$)
- 0.1 mol/L $\text{K}_4\text{Fe}(\text{CN})_6_{(\text{aq})}$ (42.2 g/L of $\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}_{(\text{s})}$)
- sat'd $(\text{NH}_4)_2\text{C}_2\text{O}_4_{(\text{aq})}$ (100 g/L of $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}_{(\text{s})}$ at room temperature)
- 0.5 mol/L $\text{Na}_2\text{HPO}_4_{(\text{aq})}$ (179 g/L of $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}_{(\text{s})}$)

2. Sample Solutions (small vial for solid mixture and dropping bottle for solution)

Known 1:

To prepare solid mixture or one litre of solution:

$\text{KNO}_3_{(\text{s})}$	+	$\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}_{(\text{s})}$	+	$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	+	$\text{AgNO}_3_{(\text{s})}$
10.1 g	+	51.3 g	+	75.0 g	+	17.0 g

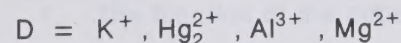
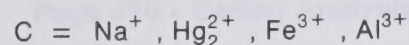
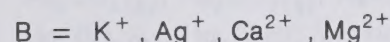
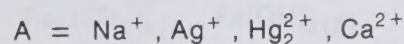
Known 2:

To prepare solid mixture or one litre of solution:

$\text{NaNO}_3_{(\text{s})}$	+	$\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}_{(\text{s})}$	+	$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}_{(\text{s})}$	+	$\text{HgNO}_3 \cdot \text{H}_2\text{O}_{(\text{s})}$
8.5 g	+	47.2 g	+	40.4 g	+	28.1 g

Note: Adding a few millilitres of 6 mol/L $\text{HNO}_3_{(\text{aq})}$ and heating will aid the dissolving of this mixture.

Unknown Samples: (Label as 1 to 16 or 32 using the table provided earlier. New numbers could be provided each year.)



Use the information given above (compound and mass) to prepare these mixtures. The stock solutions (not for student use) should be labelled A, B, C and D.

Lab J2—Pages J11-J19

1. Preparing Chlorine Water, $\text{Cl}_2_{(\text{aq})}$

Chlorine water has a limited shelf life of approximately ten days to two weeks and should be discarded after two weeks of storage. The chlorine water should be prepared and stored in a tightly stoppered container in a fume cupboard.

Add in the following order to a clean container:

150 mL of Javex

815 mL of distilled water

35 mL of 6 mol/L HCl

Stir to mix the solution. When the effervescence has ceased, transfer the chlorine water to dropping bottles for student use. Stopper the stock bottle and leave in the fume hood.

2. Saturated FeSO_4 Solution

Use the amount given below to prepare a saturated solution at room temperature. This saturated solution should be kept in well stoppered dropping bottles for no more than two weeks. ($\text{Fe}^{2+}_{(\text{aq})}$ is readily oxidized to $\text{Fe}^{3+}_{(\text{aq})}$.)

3. Solid AgCH_3COO

The solid silver acetate required for the unknown analysis should be provided in small vials. Add 0.3 g of silver acetate to a small vial, to determine approximately how full the vial must be to give 0.3 g. Estimate 0.3 g in the rest of the vials. (The amount of silver acetate used in this experiment is not critical.)

4. Reagents for Anion Analysis

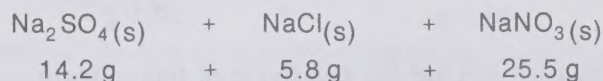
The following solutions (in dropping bottles) and solid (in vial) form a complete set of reagents.

- 0.1 mol/L $\text{Ba}(\text{NO}_3)_2(\text{aq})$ (26.1 g/L of $\text{Ba}(\text{NO}_3)_2(\text{s})$)
- 6.0 mol/L $\text{HNO}_3(\text{aq})$
- 1.0 mol/L $\text{AgNO}_3(\text{aq})$ (170 g/L of $\text{AgNO}_3(\text{s})$)
- 6.0 mol/L $\text{NH}_4\text{OH}(\text{aq})$
- 1.0 mol/L $\text{Fe}(\text{NO}_3)_3(\text{aq})$ (404 g/L of $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}(\text{s})$)
- $\text{CCl}_4(\text{l})$
- $\text{Cl}_2(\text{aq})$
- 3 mol/L $\text{H}_2\text{SO}_4(\text{aq})$
- 18 mol/L $\text{H}_2\text{SO}_4(\text{aq})$
- sat'd $\text{FeSO}_4(\text{aq})$ (400 g/L of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$)
- solid AgCH_3COO (0.3 g for each analysis; in small vials)

5. Sample Solutions

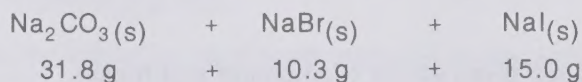
Known 1:

To prepare one litre of solution:

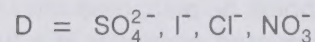
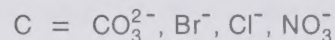
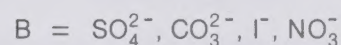
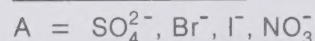


Known 2:

To prepare one litre of solution:



Unknown Samples



Use the information given above (compound and mass) to prepare for these solutions.

Lab J3—Pages J25-J28

The amounts per class given below are based on 30 students per class working, in pairs, at 15 lab stations and allowing an excess for wastage.

1. Reagents

$\text{NaHSO}_3(\text{aq})$	50.00 g/L	400 mL/class
$\text{NH}_4\text{SCN}(\text{aq})$	100.00 g/L	200 mL/class
$\text{H}_2\text{SO}_4(\text{aq})$	concentrated	20 mL/class

2. Unknown

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	solid	50 g/class
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The solid hydrated copper(II) sulfate should be in fine crystal or powder form. Large crystals may be powdered in a mortar or with an electric blender.

3. Note

Upon heating $\text{SO}_2(\text{g})$ is released. The amount is very small and not dangerous. Heating may be done in fume hoods if desired. In solution $\text{Cu}^{2+}(\text{aq})$ solutions are intensely blue and $\text{Cu}^+(\text{aq})$ are intensely green. The solution, after precipitation and filtration, may be a pale green for some samples. This does not appear to significantly affect the results obtained.

Lab J4—Pages J30-J33

Reagent Solution

To prepare 0.150 mol/L NaOH use 6.00 g/L. For a class of 30 students working in pairs, prepare about 1.5 L per class.

Notes

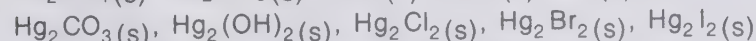
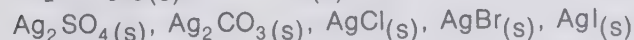
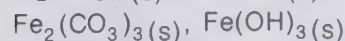
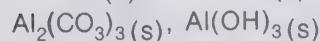
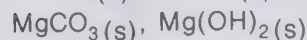
1. A slow titration is necessary to get accurate, reproducible results.
2. Different brands of tablets may contain different amounts of ASA.

Answer Key

Page J3 - Cation Analysis - Lab J1

Prelab Exercise:

The following precipitates should form:



Page J10 - Cation Analysis - Lab J1

Questions:

1. The function of the cobalt glass is to mask out the yellow flame color due to sodium impurities.
2. Conclusion: No $\text{Ag}^+(\text{aq})$ or $\text{Hg}_2^{2+}(\text{aq})$ ions are present in the sample.
Inference: The cations present in the sample may be $\text{K}^+(\text{aq})$, $\text{Na}^+(\text{aq})$, $\text{Mg}^{2+}(\text{aq})$, $\text{Ca}^{2+}(\text{aq})$, $\text{Al}^{3+}(\text{aq})$ and/or $\text{Fe}^{3+}(\text{aq})$.
3. Conclusion: The unknown sample contains $\text{Ag}^+(\text{aq})$ and/or Hg_2^{2+} and $\text{Al}^{3+}(\text{aq})$. No $\text{Fe}^{3+}(\text{aq})$ ions are present.
Inference: The cations, $\text{K}^+(\text{aq})$, $\text{Na}^+(\text{aq})$, $\text{Mg}^{2+}(\text{aq})$ and/or $\text{Ca}^{2+}(\text{aq})$, may also be present.
4. The filtrate was discarded because $\text{Na}^+(\text{aq})$ ions were added in Step 10 and the original sample has been diluted during the analysis. The original solid sample has had no reagents added and would give a much more intense flame color.
5. No $\text{Ca}^{2+}(\text{aq})$ ions are present.
6. White
7. The original sample contains $\text{Fe}^{3+}(\text{aq})$ ions. On addition of $\text{HCl}(\text{aq})$ in Step 1, $\text{FeCl}^{2+}(\text{aq})$ forms (see Step 7) which causes a yellow colored solution.

ANALYTICAL CHEMISTRY
CATION ANALYSIS — LAB J1

Day 1: Cation Analysis of Known 1

Step	Reagent Added	Observations	Conclusions	Net Equations for Observed Reactions
1	HCl(aq)	white precipitate	Ag ⁺ (aq) &/or Hg ₂ ²⁺ present	$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \longrightarrow \text{AgCl}(\text{s})$
2	NH ₄ OH(aq)	precipitate dissolves	Hg ₂ ²⁺ (aq) not present	$\text{AgCl}(\text{s}) + 2\text{NH}_3(\text{aq}) \longrightarrow \text{Ag}(\text{NH}_3)_2^+(\text{aq}) + \text{Cl}^-(\text{aq})$ (given)
3	HNO ₃ (aq)	white precipitate	Ag ⁺ (aq) confirmed	$\text{Ag}(\text{NH}_3)_2^+ + 2\text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \longrightarrow \text{AgCl}(\text{s}) + 2\text{NH}_4^+(\text{aq})$
4	NH ₄ OH(aq)	white precipitate	Al ³⁺ (aq) present	$\text{Al}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s})$
5	NaOH(aq)	precipitate dissolves	Al ³⁺ (aq) present	$\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^-(\text{aq}) \longrightarrow \text{Al}(\text{OH})_4^-(\text{aq})$
6	HCl(aq)	small amount of a white, gelatinous precipitate	Al ³⁺ (aq) confirmed	$\text{Al}(\text{OH})_4^-(\text{aq}) + \text{H}^+(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s}) + \text{H}_2\text{O}(\text{l})$ (given)
7	HCl(aq)	colorless filtrate	no Fe ³⁺ (aq) present	_____
8	K ₄ Fe(CN) ₆ (aq)			_____
9	(NH ₄) ₂ C ₂ O ₄ (aq)	no change	no Ca ²⁺ (aq) present	_____
10	NH ₄ OH(aq) and Na ₂ HPO ₄ (aq)	white precipitate	Mg ²⁺ (aq) confirmed	$\text{Mg}^{2+}(\text{aq}) + \text{NH}_3(\text{aq}) + \text{HPO}_4^{2-}(\text{aq}) \longrightarrow \text{MgNH}_4\text{PO}_4(\text{s})$ (given)
11	flame test Na ⁺ (s), K ⁺ (s)	light violet flame color	K ⁺ (aq) confirmed	_____

Cations present in Known 1: $\text{K}^+(\text{aq}), \text{Mg}^{2+}(\text{aq}), \text{Al}^{3+}(\text{aq}), \text{Ag}^+(\text{aq})$ Cations positively identified: $\text{Ag}^+(\text{aq}), \text{Al}^{3+}(\text{aq}), \text{Mg}^{2+}(\text{aq}), \text{K}^+(\text{aq})$
(Refer back to list of materials.)

ANALYTICAL CHEMISTRY
CATION ANALYSIS — LAB J1

Day 2: Cation Analysis of Known 2

Step	Reagent Added	Observations	Conclusions	Net Equations for Observed Reactions
1	HCl(aq)	white precipitate	Ag ⁺ (aq) &/or Hg ₂ ⁺ present	Hg ₂ ⁺ (aq) + 2Cl ⁻ (aq) → Hg ₂ Cl ₂ (s)
2	NH ₄ OH(aq)	precipitate turned black	Hg ₂ ⁺ confirmed	Hg ₂ Cl ₂ (s) + NH ₃ (aq) $\xrightarrow{\text{(given)}}$ HgNH ₂ Cl(s) + Hg(l) + H ⁺ (aq) + Cl ⁻ (aq)
3	HNO ₃ (aq)	no change	no Ag ⁺ (aq) present	_____
4	NH ₄ OH(aq)	rust-colored precipitate	Al ³⁺ (aq) &/or Fe ³⁺ (aq) present	Fe ³⁺ (aq) + 3OH ⁻ (aq) → Fe(OH) ₃ (s)
5	NaOH(aq)	precipitate remains in filter paper	Fe ³⁺ (aq) present	_____
6	HCl(aq)	no precipitate	no Al ³⁺ (aq) present	_____
7	HCl(aq)	precipitate dissolves yellow filtrate	Fe ³⁺ (aq) present	Fe(OH) ₃ (s) + 3H ⁺ (aq) + Cl ⁻ (aq) $\xrightarrow{\text{(given)}}$ FeCl ₃ ⁺ (aq) + 3H ₂ O(l)
8	K ₄ Fe(CN) ₆ (aq)	deep blue precipitate	Fe ³⁺ (aq) confirmed	4FeCl ₃ ⁺ (aq) + 3Fe(CN) ₆ ⁴⁻ (aq) $\xrightarrow{\text{(given)}}$ Fe ₄ [Fe(CN) ₆] ₃ (s) + 4Cl ⁻ (aq)
9	(NH ₄) ₂ C ₂ O ₄ (aq)	white precipitate	Ca ²⁺ (aq) confirmed	Ca ²⁺ (aq) + C ₂ O ₄ ²⁻ (aq) → CaC ₂ O ₄ (s)
10	NH ₄ OH(aq) and Na ₂ HPO ₄ (aq)	no change	no Mg ²⁺ (aq) present	_____
11	flame test Na(s), K(s)	bright yellow flame color	Na(aq) confirmed	_____

Cations present in Known 2: Na⁺(aq), Ca²⁺(aq), Fe³⁺(aq), Hg₂⁺(aq)
 Cations positively identified: Hg₂⁺(aq), Fe³⁺(aq), Ca²⁺(aq), Na⁺(aq)
 (Refer back to the list of materials.)

Page J12 - Anion Analysis - Lab J2

Observations:

Reactants	Halogen Present in Final Mixture	Characteristic Color of Halogen in CCl ₄ Layer
NaCl(aq) + Cl ₂ (aq)	Cl ₂ (aq)	colorless or pale yellow
NaBr(aq) + Cl ₂ (aq)	Br ₂ (aq)	brown
NaI(aq) + Cl ₂ (aq)	I ₂ (aq)	violet

Questions:

- The Cl₂(aq) in chlorine water is used to convert any Br⁻(aq) or I⁻(aq) ions into Br₂(aq) and I₂(aq) respectively in order to identify these elements by their characteristic color in CCl₄(l).
- $$\text{Cl}_2(\text{aq}) + 2\text{Br}^-(\text{aq}) \longrightarrow \text{Br}_2(\text{aq}) + 2\text{Cl}^-(\text{aq})$$

$$\text{Cl}_2(\text{aq}) + 2\text{I}^-(\text{aq}) \longrightarrow \text{I}_2(\text{aq}) + 2\text{Cl}^-(\text{aq})$$

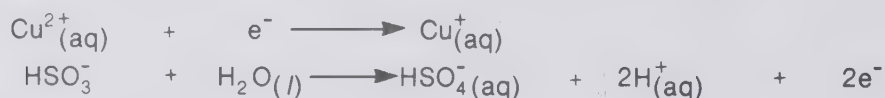
Pages J23-J24 - Calculations for Analysis

- | | |
|------------|------------|
| 1. 0.218 | 6. 5.00 % |
| 2. 0.885 g | 7. 1.5 % |
| 3. 0.142 | 8. 55.0% |
| 4. 0.160 g | 9. 38.5 % |
| 5. 4.14 % | 10. 17.9 g |

Page J25 - Gravimetric Analysis for Copper - Lab J3

Teacher Information

The reaction of Cu²⁺(aq) with HSO₃⁻(aq) is a redox reaction. The reduction and oxidation half reactions are given below.



Prelab Exercise

- Treat the solid sample with hot nitric acid.
- A solution of a compound containing Cl⁻ or SO₄²⁻ ions should be added. The cation should be a noninterfering ion, such as Na⁺.

Page J27 - Gravimetric Analysis for Copper - Lab J3

Observations:

Day 1: mass of weighing boat 1.61 g
 mass of sample 2.50 g
 mass of boat plus sample 4.11 g

Day 2: mass of filter paper 1.12 g

Day 3: mass of filter paper plus precipitate 2.30 g

ANALYTICAL CHEMISTRY
ANION ANALYSIS — LAB J2

Day 1: Anion Analysis of Known 1

Step	Reagent Added	Observations	Conclusions	Net Equations for Observed Reactions
1	Ba(NO ₃) ₂ (aq)	white precipitate	CO ₃ ²⁻ (aq) &/or SO ₄ ²⁻ (aq) present	Ba ²⁺ (aq) + SO ₄ ²⁻ (aq) → BaSO ₄ (s)
2	HNO ₃ (aq)	no change	SO ₄ ²⁻ (aq) confirmed no CO ₃ ²⁻ (aq) present	_____
3	AgNO ₃ (aq)	white precipitate	Cl ⁻ (aq) present	Ag ⁺ (aq) + Cl ⁻ (aq) → AgCl (s)
4	HNO ₃ (aq)	no change		_____
5	NH ₄ OH (aq)	precipitate dissolves	Cl ⁻ (aq) present	AgCl (s) + 2NH ₃ (aq) → Ag(NH ₃) ₂ ⁺ (aq) + Cl ⁻ (aq)
6	HNO ₃ (aq)	white precipitate	Cl ⁻ (aq) confirmed	Ag(NH ₃) ₂ ⁺ (aq) + 2H ⁺ (aq) + Cl ⁻ (aq) → AgCl (s) + 2NH ₄ ⁺ (aq)
7	Fe(NO ₃) ₃ (aq)	no change	no I ⁻ (aq) present	_____
7	CCl ₄ (l)	_____		_____
9	Cl ₂ (aq)	no change	no Br ⁻ (aq) present	_____
9	CCl ₄ (l)	_____		_____
10	3 mol/L H ₂ SO ₄ (aq) + FeSO ₄ (aq) + 18 mol/L H ₂ SO ₄ (l)	brown ring where liquids meet	NO ₃ ⁻ (aq) confirmed	(given) NO ₃ ⁻ (aq) + 4Fe ²⁺ (aq) + 4H ⁺ (aq) → Fe(NO) ²⁺ (aq) + 3Fe ³⁺ (aq) + 2H ₂ O (l)
11	AgCH ₃ COO (s)	_____		_____

Anions present in Known 1 _____
(Refer to the materials list.)

Anions positively identified _____
SO₄²⁻ (aq), Cl⁻ (aq), NO₃⁻ (aq)

ANALYTICAL CHEMISTRY
ANION ANALYSIS — LAB J2

Day 2: Anion Analysis of Known 2

Step	Reagent Added	Observations	Conclusions	Net Equations for Observed Reactions
1	Ba(NO ₃) ₂ (aq)	white precipitate	CO ₃ ²⁻ (aq) &/or SO ₄ ²⁻ (aq) present	Ba ²⁺ (aq) + CO ₃ ²⁻ (aq) → BaCO ₃ (s)
2	HNO ₃ (aq)	precipitate dissolves gas bubbles	CO ₃ ²⁻ (aq) present no SO ₄ ²⁻ present	2H ⁺ (aq) + BaCO ₃ (s) → Ba ²⁺ (aq) + CO ₂ (g) + H ₂ O(l) (given)
3	AgNO ₃ (aq)	yellow precipitate	CO ₃ ²⁻ (aq), Cl ⁻ (aq), Br ⁻ (aq) &/or I ⁻ (aq) present	Ag ⁺ (aq) + Br ⁻ (aq) → AgBr(s) Ag ⁺ (aq) + I ⁻ (aq) → AgI(s)
4	HNO ₃ (aq)	gas bubbles	CO ₃ ²⁻ (aq) present	2H ⁺ (aq) + CO ₃ ²⁻ (aq) → CO ₂ (g) + H ₂ O(l)
5	NH ₄ OH(aq)	precipitate remains clear filtrate	Br ⁻ (aq) &/or I ⁻ (aq) present	_____
6	HNO ₃ (aq)	no change	no Cl ⁻ (aq) present	_____
7	Fe(NO ₃) ₃ (aq)	brown color	I ⁻ (aq) present	2Fe ³⁺ (aq) + 2I ⁻ (aq) → 2Fe ²⁺ (aq) + I ₂ (aq)
7	CCl ₄ (l)	violet color	I ⁻ (aq) confirmed	I ₂ (aq) → I ₂ (CCl ₄)
9	Cl ₂ (aq)	brown color	Br ⁻ (aq) present	2Fe ³⁺ (aq) + 2Br ⁻ (aq) → 2Fe ²⁺ (aq) + Br ₂ (aq)
9	CCl ₄ (l)	yellow-brown color	Br ⁻ (aq) confirmed	Br ₂ (aq) → Br ₂ (CCl ₄)
10	3 mol/L H ₂ SO ₄ (aq) + FeSO ₄ (aq) + 18 mol/L H ₂ SO ₄ (l)	no change	no NO ₃ ⁻ (aq) present	_____
11	AgCH ₃ COO(s)	yellow colored solid	Br ⁻ (aq) and I ⁻ (aq) removed	AgCH ₃ COO(s) + Br ⁻ (aq) → AgBr(s) + CH ₃ COO ⁻ (aq) AgCH ₃ COO(s) + I ⁻ (aq) → AgI(s) + CH ₃ COO ⁻ (aq)

Anions present in Known 2 _____ **CO₃²⁻(aq), Br⁻(aq), I⁻(aq) - Anions positively identified** _____
(Refer to the materials list.)

CO₃²⁻(aq), Br⁻(aq), I⁻(aq)

Calculations and Questions: **Pages J27-J28 - Gravimetric Analysis for Copper - Lab J3**

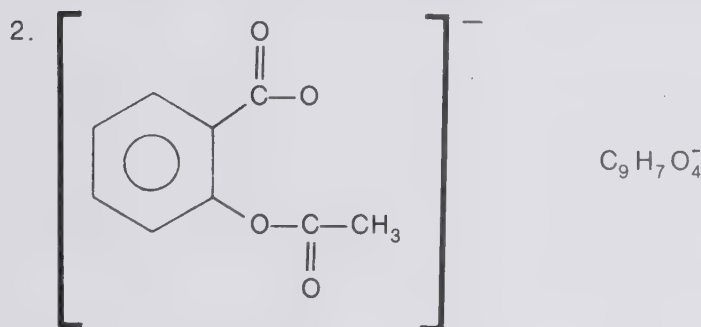
1. Sodium bisulfite solution converts the $\text{Cu}^{2+}_{(\text{aq})}$ ions to $\text{Cu}^{+}_{(\text{aq})}$ ions.
2. $2\text{Cu}^{2+}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} + \text{HSO}_3^{-}_{(\text{aq})} \longrightarrow \text{HSO}_4^{-}_{(\text{aq})} + 2\text{H}^{+}_{(\text{aq})} + 2\text{Cu}^{+}_{(\text{aq})}$
3. $C_{\text{NaHSO}_3} = 0.4803 \text{ mol/L}$
 $C_{\text{NH}_4\text{SCN}} = 1.314 \text{ mol/L}$
4. $\text{Cu}^{+}_{(\text{aq})} + \text{SCN}^{-}_{(\text{aq})} \longrightarrow \text{CuSCN}_{(\text{s})}$
5. 0.616 g (ideally 0.635 g)
6. 24.6 % (ideally 25.4 %)
7. 3.1 %
8. - incomplete conversion of $\text{Cu}^{2+}_{(\text{aq})}$ to $\text{Cu}^{+}_{(\text{aq})}$
- loss of precipitate
- incomplete drying of precipitate

Page J29 - Volumetric Analysis

1. $\text{H}_2\text{SO}_4_{(\text{aq})} + 2\text{NaOH}_{(\text{aq})} \longrightarrow \text{Na}_2\text{SO}_4_{(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})}$
2. 0.648 mol/L
3. Yes, vinegar is normally 1.0 mol/L

Prelab Exercise: **Page J30 - Volumetric Analysis for ASA - Lab J4**

1. One tablet does not give enough accuracy on a centigram balance. Ten tablets will give three figure accuracy, but more would be unnecessary in this experiment.



3. $\text{HC}_9\text{H}_7\text{O}_4_{(\text{aq})} + \text{NaOH}_{(\text{aq})} \longrightarrow \text{NaC}_9\text{H}_7\text{O}_4_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$

Observations: **Page J31 - Volumetric Analysis for ASA - Lab J4**

mass of tablet	<u>0.378 g</u>
final buret reading	<u>12.1 mL</u>
initial buret reading	<u>0.6 mL</u>
volume of 0.150 mol/L NaOH solution used	<u>11.5 mL</u>

Calculations and Questions: **Pages J31-J33 - Volumetric Analysis for ASA - Lab J4**

1. 0.311 g
2. 82.3 % ASA, 17.7 % filler
3. 0.325 g
4. 0.00222 mol
5. 0.00222 mol
6. 19.0 mol/L

7.	10.0 mol/L	0.222 mL
	1.00 mol/L	2.22 mL
	0.100 mol/L	22.2 mL
	0.0100 mol/L	222 mL

8. More than 10 mL gives 3-figure accuracy from the buret.
Less than 50 mL avoids refilling the buret during a titration.
9. The 0.100 mol/L solution is most likely to give a volume within the 10-50 mL limits.
10. Dissolve 20.00 g of solid NaOH in some pure water and bulk the volume to 5.00 L.

Pages J34-J35: Overview

1. $\text{Al}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s})$
 $\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^{-}(\text{aq}) \longrightarrow \text{Al}(\text{OH})_4^{-}(\text{aq})$
 $\text{Ag}^{+}(\text{aq}) + \text{Br}^{-}(\text{aq}) \longrightarrow \text{AgBr}(\text{s})$
 $\text{Cl}_2(\text{aq}) + 2\text{Br}^{-}(\text{aq}) \longrightarrow \text{Br}_2(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$
 $\text{Br}_2(\text{aq}) \longrightarrow \text{Br}_2(\text{CCl}_4)$
2. AlBr_3
3. 3.01 %
4. 0.520 mol/L
5. 25.9 %

Foods and Their Analogs

ALCHEM ELECTIVE TEACHERS' GUIDE
FOODS AND THEIR ANALOGS

1

Unit O - TEACHER INFORMATION

This unit, as an elective unit, may be expanded upon or shortened with no serious effect on the student. Much of the work is new but wherever possible questions relate to the core units.

Discussions should relate to problems involved in our misuse of chemicals and to problems involved in studying effects of chemicals on life.

e.g., When large doses of a chemical cause cancer in rats, does that mean that small doses over long periods of time will cause cancer in humans? Is the rat metabolism enough like human metabolism to tell? Should animals be sacrificed to save human life? How sacred is human life?

These questions could lead to some lively discussions. This unit might be a good place to attempt to draw a line between scientific objectivity and value judgements.

Suggested Lab

Preparation of Detergents

Objective:

1. To prepare a detergent.
2. To test some of the detergent's properties.

Materials:

- | | |
|----------------------------|-------------------------------|
| 11.0 mL - dodecanol | 1 - 10 mL graduated cylinder |
| 3.5 mL - (conc.) H_2SO_4 | 1 - 25 mL graduated cylinder |
| 15 g - NaCl | - beaker one-half full of ice |
| 17 mL - 2 mol/L NaOH | |
| 4 drops - phenolphthalein | |
| 2 - 100 mL beaker | |
| 1 - 150 mL beaker | |
| 1 - wire gauze | |

Procedure:

1. Obtain 11.0 mL of dodecanol in a 25 mL graduated cylinder and place it in a 100 mL beaker.
2. Obtain 3.5 mL of conc. H_2SO_4 in a 10 mL graduated cylinder and slowly add it to the dodecanol. Stir the solution slowly for 2 min and then let it stand for 10 min.
Caution: Concentrated H_2SO_4 is corrosive.
3. Fill a 150 mL beaker half full of ice and add 15 g of NaCl. Mix the ice and salt. Add water to raise the level to 75 mL. Let the mixture stand.
4. Obtain 17 mL of 2 mol/L NaOH in a clean 25 mL graduated cylinder and add it to a 100 mL beaker containing 4 drops of phenolphthalein.
5. After the 10 min is up pour the dodecanol-sulfuric acid solution into the NaOH solution. Stir the mixture until the pink color disappears.
6. Pour the detergent formed into the ice-salt bath. Stir vigorously to break up the detergent. Filter the precipitate through a wire gauze and allow to dry.
7. Carry out a series of procedures identical to the Day II procedure for Lab 01, the saponification lab, to test the detergent.

Questions:

1. Does the detergent produced form suds?
2. What effect does the addition of Mg^{2+} and Ca^{2+} have on the detergent?
3. Does the oil dissolve in the detergent solution?
4. What are the observed advantages of a detergent over a soap?

Saponification - Lab O1

Materials:

The list of materials below is given in class requirements on the left and individual station requirements on the right.

Day 1:

<u>Class (16 Stations)</u>	<u>Each Station</u>
16 - 250 mL beakers	1
16 - 100 mL beakers	1
16 - 75 mL evaporating dishes	1
16 - stirring rods with rubber policemen	1
16 - scoopulas	1
16 - crucible tongs	1
16 - bunsen burners	1
16 - 75 mm watch glasses	1
4 - stock bottles NaOH pellets	3.4 g
55 - NaOH pellets in 16 vials	23 g
1 - 0.5 kg lard - cut into 20 equal portions, or	3.4 g
368 g - lard or grease (could be bacon grease or grease from other meats)	

Day 2:

96 - 18 x 150 mm test tubes	6
200 mL - 1 mol/L $Mg(NO_3)_2$ (29.7 g in 200 mL solution)	10 mL
200 mL - 1 mol/L $Ca(NO_3)_2$ (32.8 g in 200 mL solution)	10 mL
16 - scoopulas	1
96 - #1 rubber stoppers	6
4 - stock bottles light oil (kerosene, benzene, cyclohexane) with a large dropper for each	a few drops

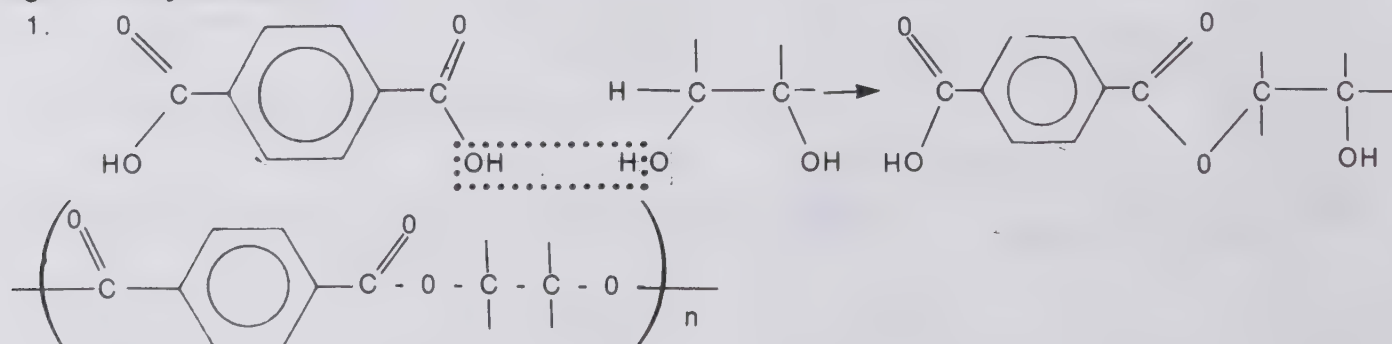
POLYESTERS Lab or Demo

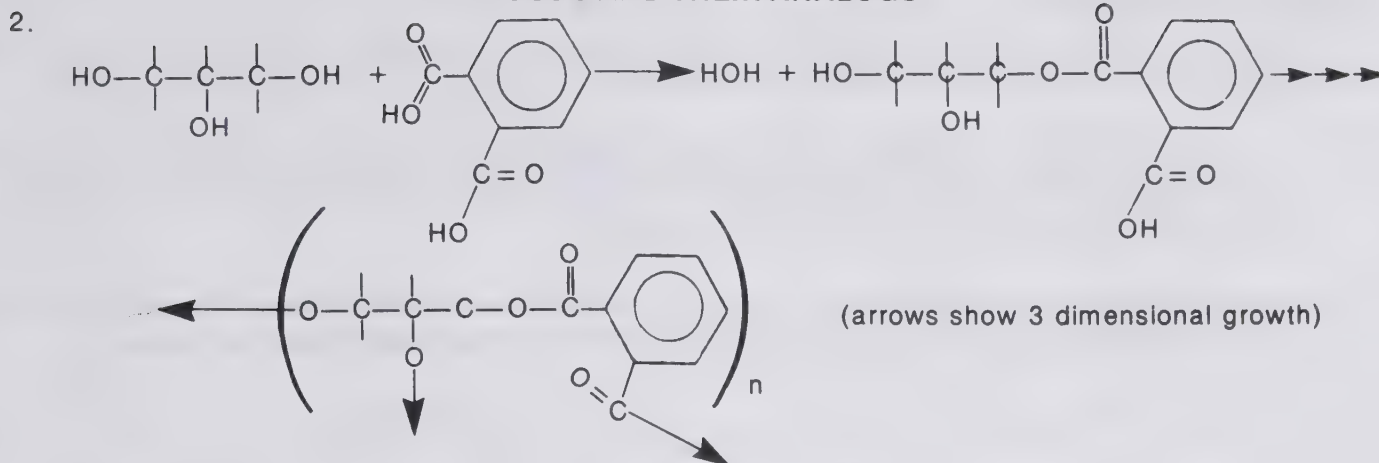
A demonstration using resins might be developed to lead into a more detailed discussion of catalysts and temperature effects on rates of reaction.

Materials:

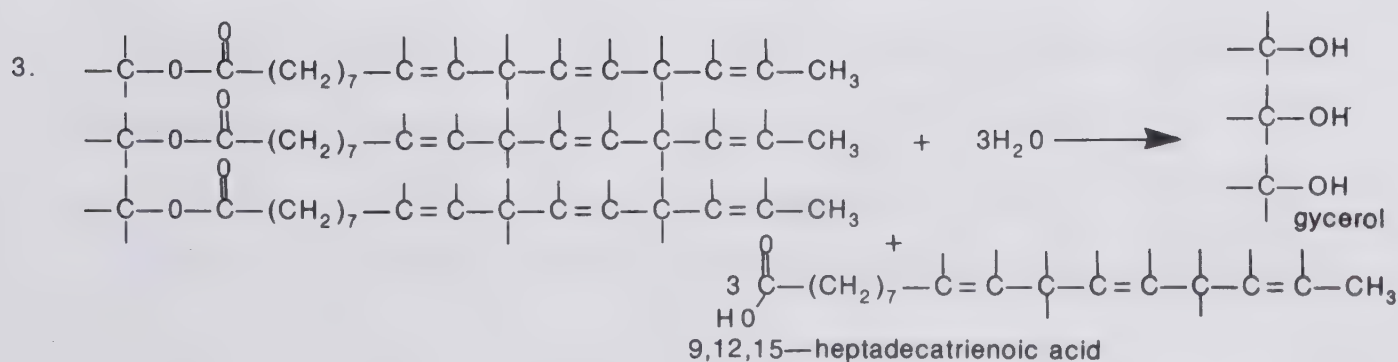
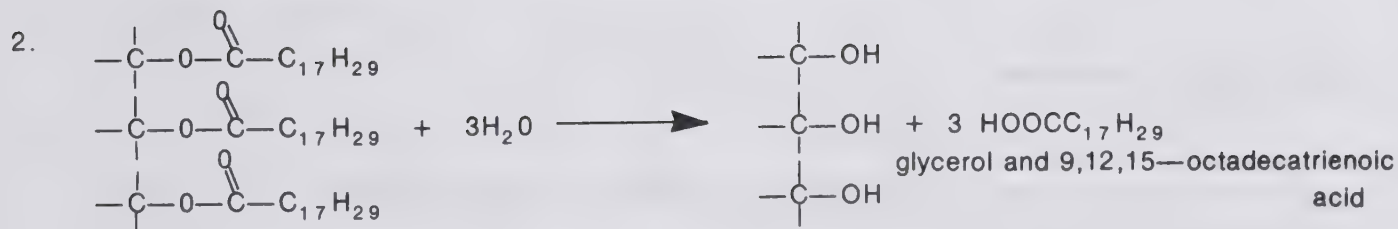
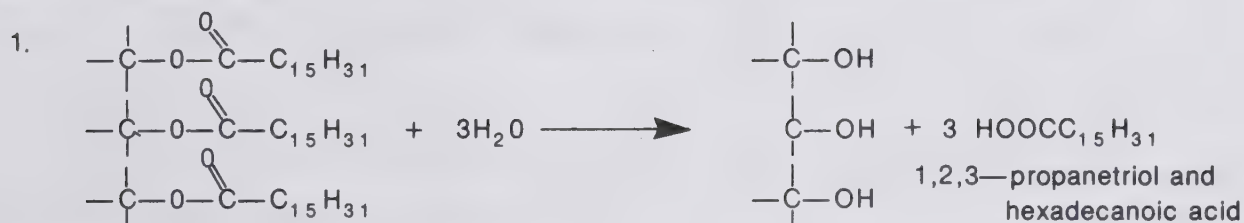
The list of materials below is given in class requirements on the left and individual station requirements on the right.

Part A:	<u>Each Station</u>	Part B:	<u>Each Station</u>
<u>Class (16 Stations)</u>		<u>Class (16 Stations)</u>	
16 - 250 mL beaker	1	1 - commercial fibreglass kits (contains resin mixture and catalyst)	1
16 - old 150 mL or 250 mL beakers (to be thrown away)	1	48 - aluminum cup cake or tart tins	3
16 - plastic boats	1	16 - old graduated 50 mL beakers	1
16 - glass stirring rods	1	16 - stirring rods	1
16 - ring stands	1	48 - asbestos pads	3
16 - asbestos wire gauzes	1	16 - scoopulas	1
16 - bunsen burners	1	16 - small nails or needles to open new catalyst dispenser	1
16 - strikers	1	- acetone or laundry detergent (for clean up)	
16 - molds (optional)	1	- paper towels	
16 - 150 °C thermometers	1		
16 - mortars	1		
16 - pestles	1		
about 320 g - phthalic anhydride	20 g		
about 40 g - glycerol	2.5 g		
- acetone for cleaning up			



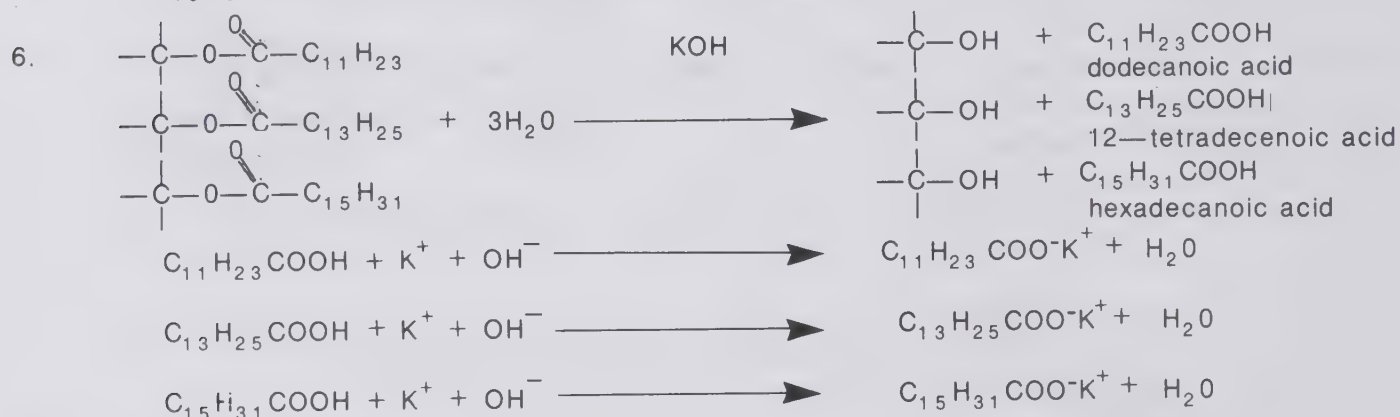
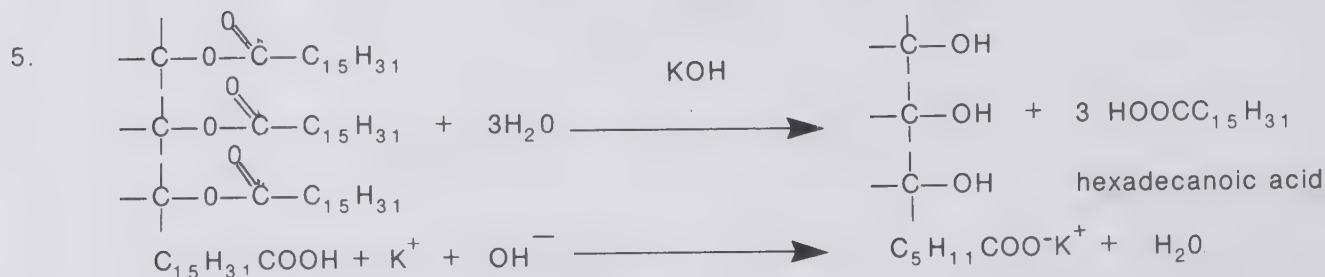
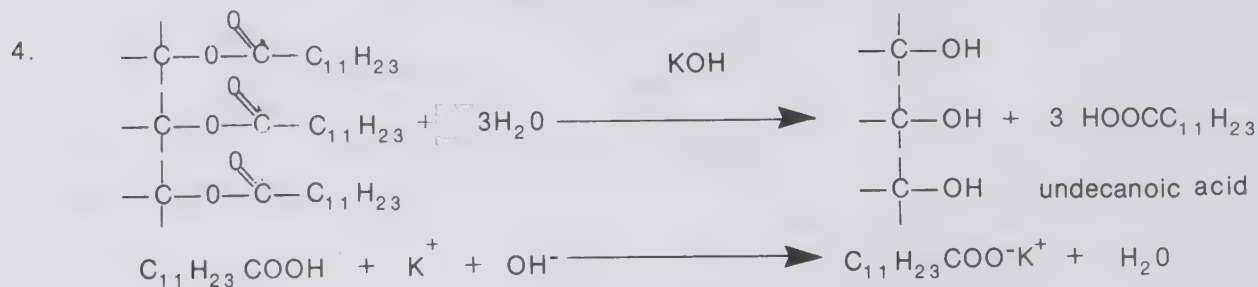


Page 013 Hydrolysis



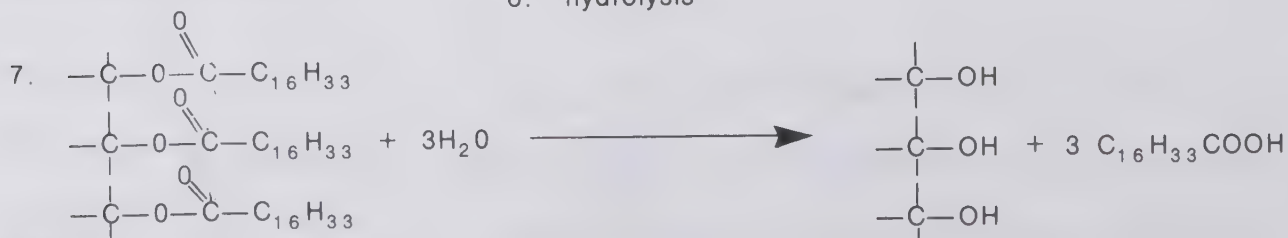
Page 018 Lab Questions

1. Sodium hydroxide acts as a catalyst in the hydrolysis reaction and the OH^- neutralizes the organic acid produced.
2. Calcium and magnesium stearates are low solubility substances. In hard water the stearate ion (which is part of the soap) will precipitate with magnesium or calcium ions thus effectively removing the soap from the water. The cleaning action will be greatly decreased.
3. This soap is probably still quite basic and would irritate the skin. It would also probably adversely affect some materials and in hard water would deposit calcium or magnesium stearates on clothes.



Page 025 Lipids Overview

1. acids, alcohols, esterification, esters
2. glycerol or glycerine
3. Animal fats are usually saturated, plant oils are usually polyunsaturated.
4. polymer, monomer, dimer.
5. polyester
6. hydrolysis



8. respiration.
9. Kidney stones, gallstones are made of cholesterol. Arteriosclerosis is another problem.

ALCHEM ELECTIVES TEACHERS' GUIDE

FOODS AND THEIR ANALOGS

10. vegetable oils, animal fats, hydrogenated lipids.
11. It speeds up a reaction. It is not itself consumed.
12. The rule means that substances which have similar chemical structures will tend to dissolve one another (be miscible). (Polar substances will dissolve other polar substances and nonpolar substances will dissolve other nonpolar substances.)
13. The nonpolar parts of the soap molecules bond with the nonpolar grease and oil and the polar parts of the soap molecules bond with the (polar) water. Thus the water (polar) and dirt (nonpolar) are bonded together by the soap.
14. enzymes.
15. Mg^{2+} or Ca^{2+} .
16. Biodegradable means the substances can be ingested by organisms and broken down into natural materials with no harm to the organism or that the substance decomposes chemically over time into natural substances.
17. surfactant.
18. to react with and remove from solution, but not precipitate.
19. sequestering agent pH regulator.
20. that extensive use over-fertilizes algae in rivers and streams and lakes
21. Enzymes should be both polar and nonpolar. Their polarity will enable them to dissolve in water and their nonpolarity will enable them to dissolve blood and other nonpolar stains.
22. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$
23. The pH will increase.
24. Laundry detergents and household cleaners should be kept out of the reach of small children, preferably in a locked cupboard.
25. $CO_3^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s)$
 $CO_3^{2-}(aq) + Mg^{2+}(aq) \rightarrow MgCO_3(s)$
26. Question involving values.

Pro Phosphates

excellent builders - good sequestering agent
 - raises pH

biodegradable
 other builders also create problems

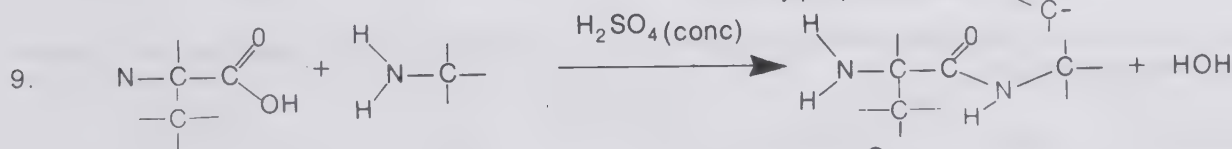
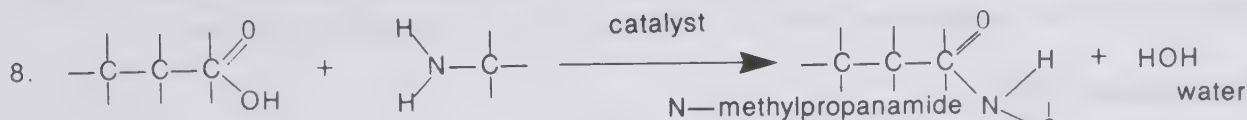
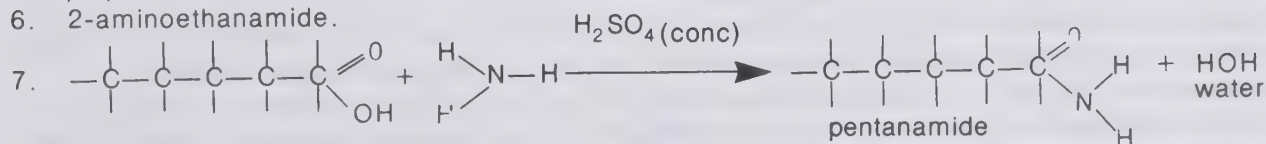
Con Phosphates

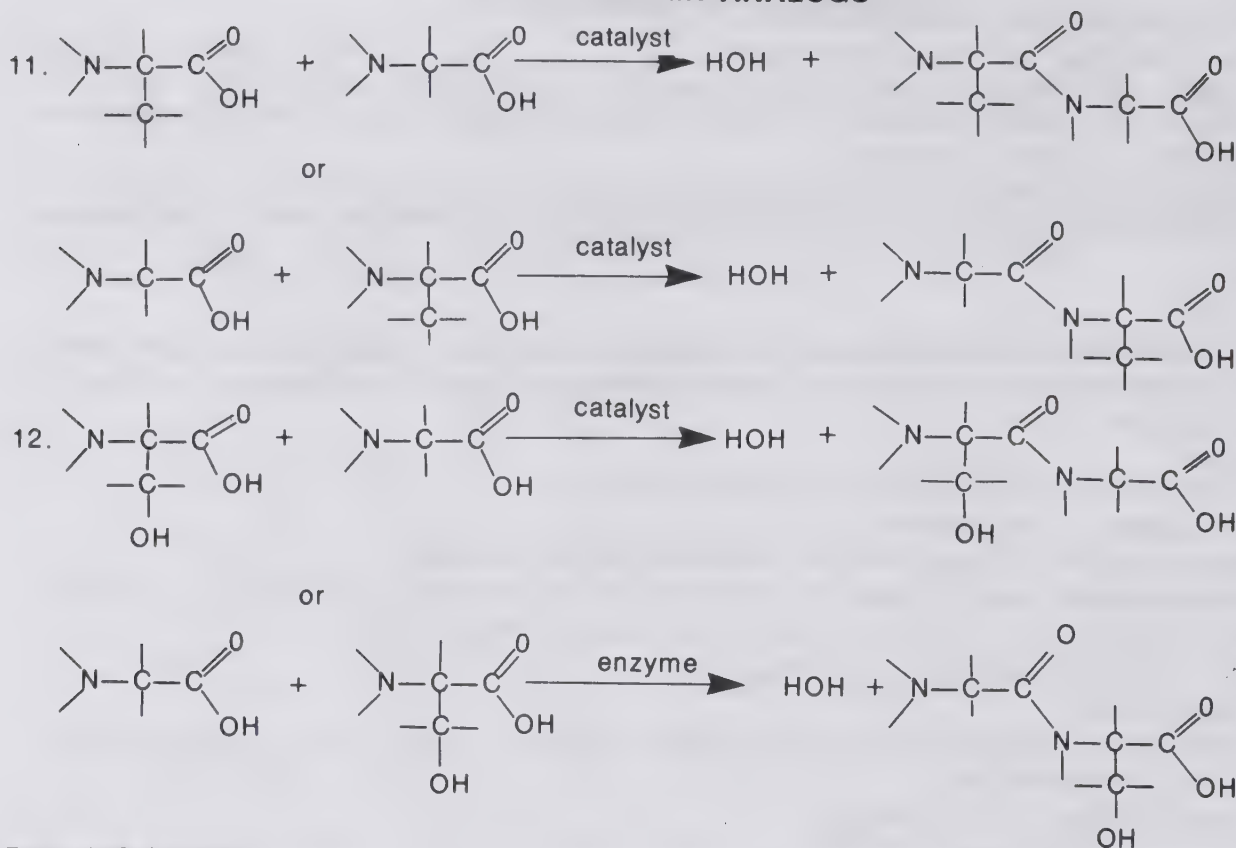
excessive use builds up algae
 other builders may be available
 clothes still get fairly clean without phosphates

27. pH > 7 shampoos would be better cleaners because detergents work better in basic conditions.

Page 031 Amines, Amides and Amino Acids

1. butylamine or 1-aminobutane.
2. N-pentylethanamide.
3. ethylamine or aminoethane.
4. N-methyl-N-ethylbutylamine or N-methyl-N-ethyl-1-aminobutane.
5. propanamide
6. 2-aminoethanamide.



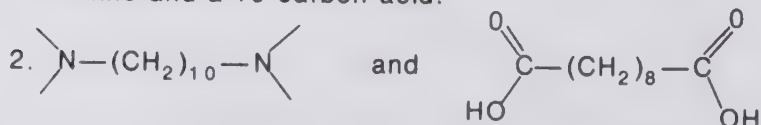


Page 036 Proteins

- False. The alpha carbon is the carbon that the carboxyl group is bonded to.
- polypeptide
- peptide amide
- amino acid
- False. Proteins have specific functions, polypeptides do not. Proteins are also generally larger than polypeptides.
- meat, cheese, soyabean, rapeseed, milk and fish.
- It is important to eat foods rich in amino acids, particularly the essential amino acids. The body synthesizes its own proteins from amino acids.
- enzymes
- connective tissues, hair, nails, skin, bone and muscle.
- amino acids, enzymes.
- hydrolysis.
- 1,2,3-propanetriol, fatty acids amino acids
- The food protein is hydrolyzed in the stomach and the resulting amino acids are absorbed into the blood stream and transported to individual cells where they are synthesized into specific proteins.
- Dietary fats are hydrolyzed and resynthesized as fatty tissue, which forms the energy reserve of the body. Fats are metabolized to provide energy only if insufficient carbohydrate is present. Dietary proteins are hydrolyzed and resynthesized as structural material (proteins) or catalysts (enzymes).

Page 039 Production of Nylon

- Nylon 6—6 is made from a 6 carbon amine and a 6 carbon acid. Nylon 6—10 is made from a 6 carbon amine and a 10 carbon acid.

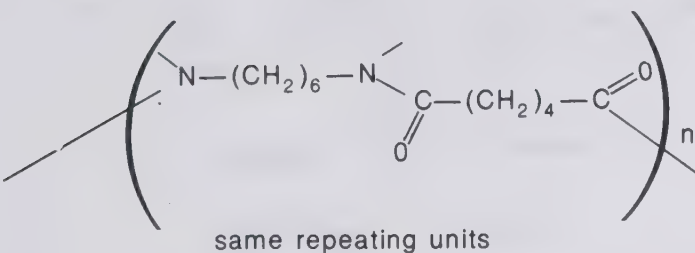


ALCHEM ELECTIVES TEACHERS' GUIDE
FOODS AND THEIR ANALOGS

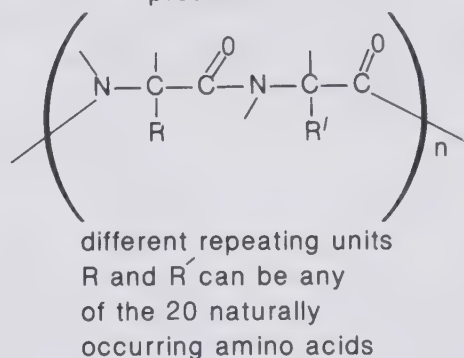
8

3. Nylon is an amide polymer of 2 monomer units. Proteins are amide polymers of 20 different monomer units.
 eg.

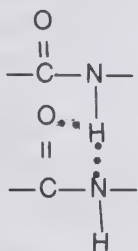
nylon



protein



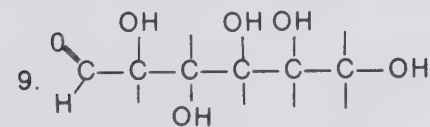
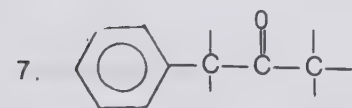
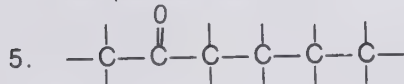
4. 1,6—diaminohexane is soluble since the polar amino groups can interact with water. Tetrachloroethene is not soluble in water because it is nonpolar. Nylon is not polar enough to dissolve in water and sebacyl chloride reacts with water.
5. The types of intermolecular bonding present would be London dispersion forces and hydrogen bonding. Hydrogen bonding is shown below; London dispersion forces are universal.



Page 041 Aldehydes and Ketones

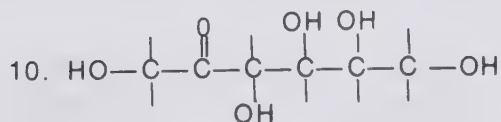
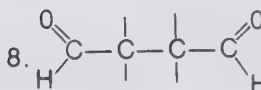
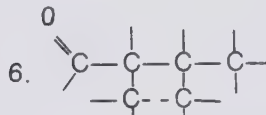
1. butanal

3. 3—pentanone

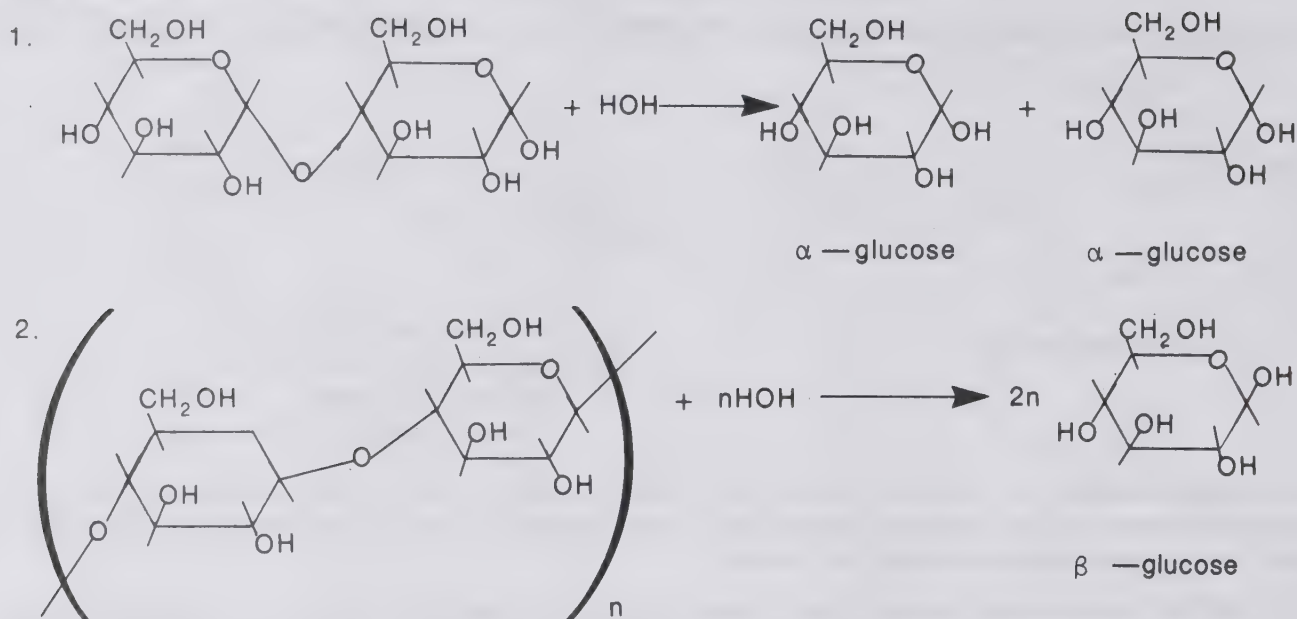


2. pentanal

4. 3—methyl—2—butanone



Page 047 Carbohydrates



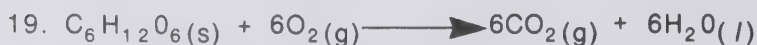
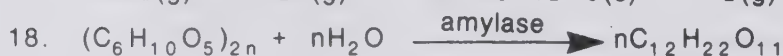
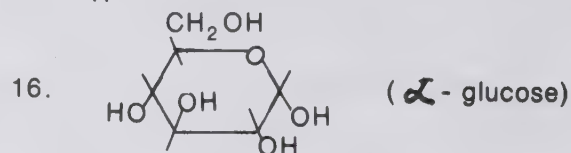
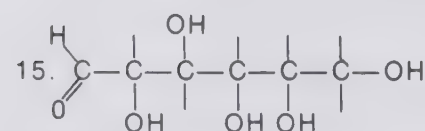
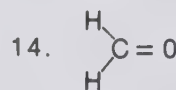
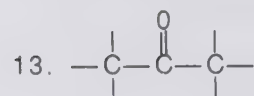
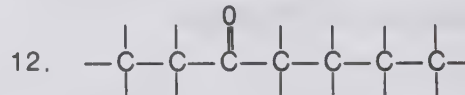
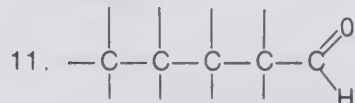
Page 051 Carbohydrates

1. The degradation products are carbon and water.
2. aldehyde, octanal

3. ketone, 2—hexanone
4. aldoses
5. ketoses
6. 5, 6
7. ketone, alcohol
8. one, al

9. A water molecule is eliminated when the bond joining the two monosaccharides forms.

10. starches



21. aldehyde

hexanal

22. ketone

butanone

23. disaccharide

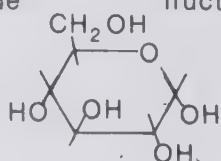
sucrose

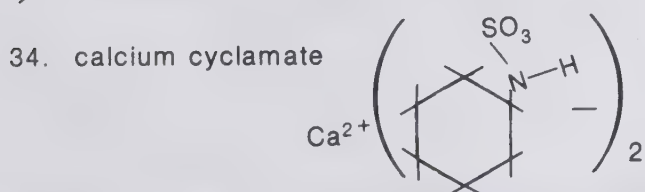
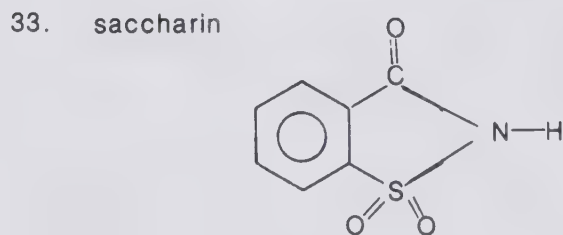
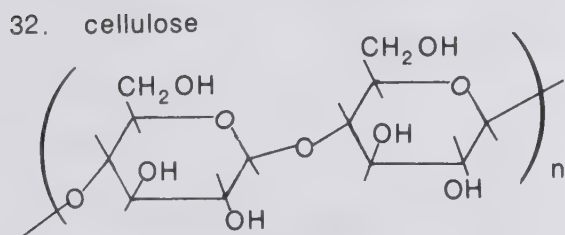
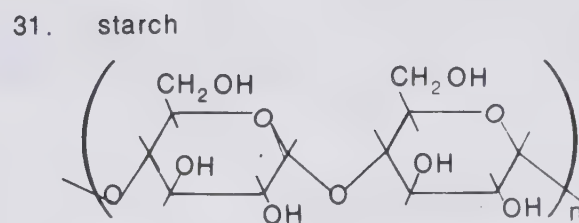
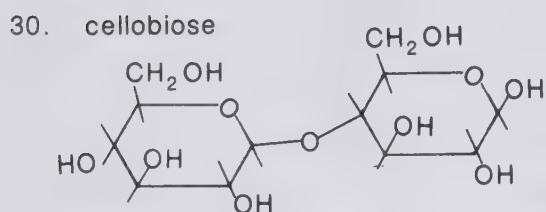
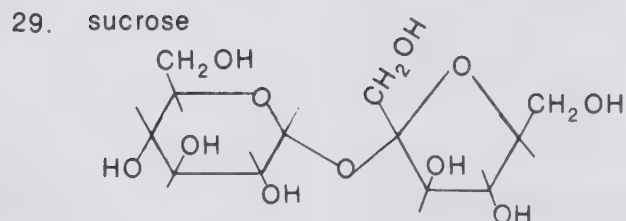
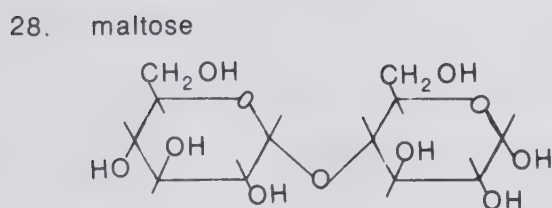
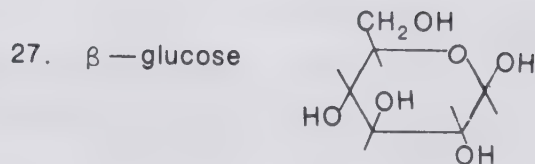
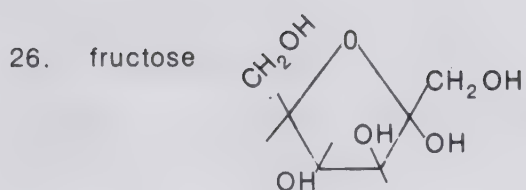
24. monosaccharide

fructose

25.

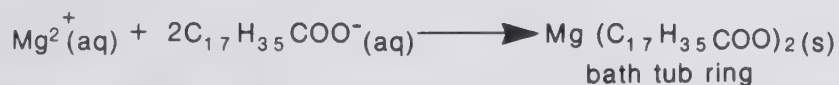
α — glucose



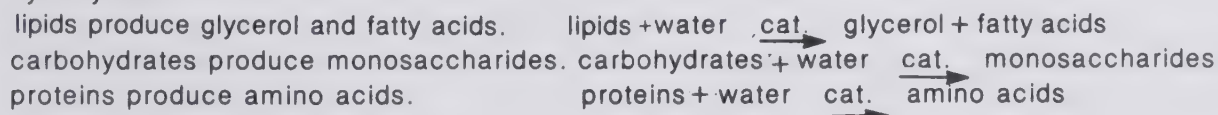


Page 055 Lipids - Carbohydrates - Proteins Overview

1. Use of soaps in hard water results in precipitation of magnesium and calcium stearates.



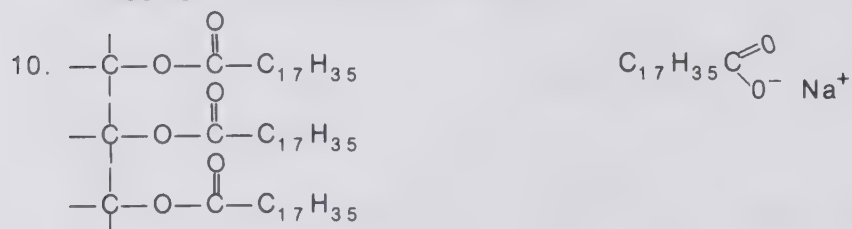
2. Starch is digestible by humans, cellulose is not. Starch has α —1,4 bonding while cellulose has β —1,4 bonding between glucose residues.
3. Respiration is the stepwise redox reactions which occur in the body to produce energy. Digestion is the changing of large food molecules into smaller molecules which can be absorbed and used by the body.
4. Eight amino acids are called essential because the body cannot synthesize them and therefore they must be included in the diet.
5. Both substances were introduced as substitutes for existing molecules - NTA as a substitute for phosphates in detergents and saccharin as a substitute for sucrose. Both substances were removed from the market when they were found to be much more harmful than the substances they replaced.
6. hydrolysis



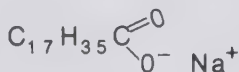
ALCHEM ELECTIVES TEACHERS' GUIDE
FOODS AND THEIR ANALOGS

11

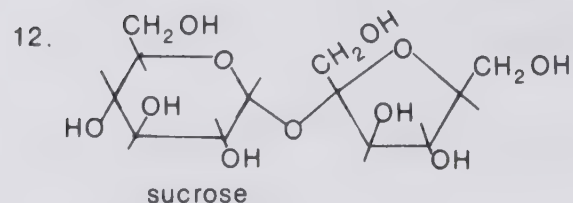
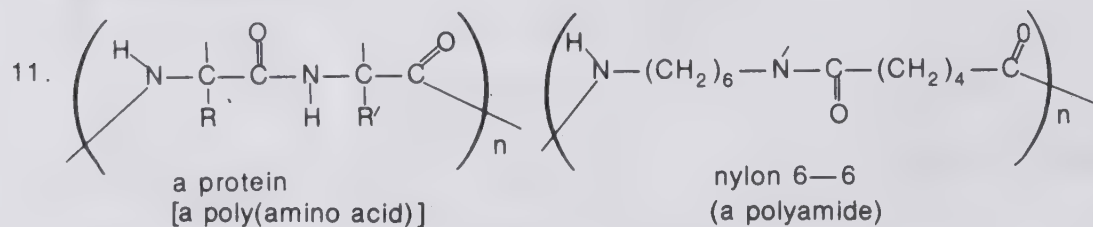
7. beta glucose (β — glucose)
cellobiose
8. Nylon because both silk and nylon are polyamides.
9. The STPP ion is biodegradable to simple phosphate ions ($\text{PO}_4^{3-}(\text{aq})$).
Phosphates fertilize the growth of algae.
Clogging of streams and rivers results.



glyceryltriostadecanoate
(glyceryl tristearate)



sodium stearate
(soap)



- | | | |
|---|------------|--------------------|
| 13. substance | molar mass | heat of combustion |
| $\text{C}_6\text{H}_{12}\text{O}_6$ | 180 g/mol | 15.6 kJ/g |
| 14. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ | 342 g/mol | 16.5 kJ/g |
| 15. $\text{C}_{15}\text{H}_{26}\text{O}_6$ | 302 g/mol | 26.9 kJ/g |

Carbohydrates are metabolized quickly and thus the body gets needed energy from saccharides before other types of foods can be metabolized. If there is insufficient carbohydrate available, fats will be respired to obtain energy but this is a more time consuming process.

ALCHEM ELECTIVES TEACHERS' GUIDE
FOODS AND THEIR ANALOGS

12

	Food	Lipid	Protein	Carbohydrate
16.	Source (see Appendix 1)	fish, meat, salad oils and dressings margarine, butter, whole milk, cream, cheese, ice cream	complete sources are meat, milk, cheese, eggs, fish, poultry	starchy plants (potatoes, rice) sweet tasting foods (saccharides.) (which are generally deficient in other nutrients))
17.	Function	supplies energy, aids in the absorption of fat soluble vitamins (A,D,E and K) (An optimum amount of stored fat will provide reserve energy, insulate and protect body parts and improve appearance.)	builds and repairs body tissues(Complete sources provide all the essential amino acids in reasonable amounts for building protein for body functions.)	supplies energy, assists in the utilization of fat, spares protein from being used for energy
18.	Digestion	hydrolysis to 1,2,3—propanetriol and fatty acids	hydrolysis to amino acids	hydrolysis to monosaccharides
19.	Respiration	usually reconstituted but if energy is required, are slowly respired to CO ₂ and H ₂ O	not usually respired but can be	enzymes(i.e., insulin) catalyzed respiration to CO ₂ and H ₂ O
20.	Synthesis (Resynthesis) (Reconstitution)	glycerol and fatty acids reconstituted and stored as glycogen (energy storage) or fatty tissue.)	amino acids used to make body proteins and enzymes	excess(beyond energy needs) carbohydrate is converted to glycogen (body starch) and body fat

Ethylene and its Derivatives

ALCHEM ELECTIVES TEACHERS' GUIDE ETHYLENE AND ITS DERIVATIVES

1

General Information

Ethylene and its Derivatives primarily requires a good background in organic chemistry and chemical bonding. The unit could be used as an elective unit for ALCHEM 20 or ALCHEM 30. If it is used for ALCHEM 20 then the few questions relating to energy calculations and Le Chatelier's Principle could be omitted without significantly affecting the continuity of the unit.

The initial part of the Ethylene unit should be done quickly and is there more to present a context for the rest of the unit than for any other reason. The latter part of the unit appears to be independent study oriented but the teacher should spend class time going over the questions with the whole class. A context to the questions must be provided by the teacher. Frequent references to the unit flowchart are necessary to indicate to the students where they are at now. A kit of demo materials should be prepared(see below) for spontaneous reference during classtime.

As the unit now stands(in 1979), in the latter part of the unit students start to get bored with the multitude of equations to be written. A revision in the near future will eliminate some of the historical vs. commercial repetitions and replace them with a lab on the production of polystyrene and, perhaps, a polyester demo(see this demo in *Foods and their Analogs*). Also, a section on the production of vinyl acetate and polyvinyl acetate will be added. The overall context of the revised unit will also be more Canadian than Albertan.

In 1980 the ethane and ethylene production by the Edmonton CIL plant was shut down. Ethylene for the CIL polyethylene plant is now purchased from the Joffre plant. Watch the newspaper for new developments.

Unit Demo Kit

- Ethylene Product Tree(as front cover) available from the Alberta Department of Business and Tourism
- old catalogues for illustrating the abundance of polymers on the market
- the following bottles labelled“ _____(simulated)” to help students (and teachers) visualize the state of matter of the compounds in the unit.(Use air for gases and water for liquids.)

- | | | |
|---|--------------------------------------|-----------------------------------|
| - ethane (simulated gas) | - ethylene oxide(simulated gas) | - benzene(simulated liquid) |
| - ethylene(simulated gas) | - ethylene glycol(simulated liquid) | - ethyl benzene(simulated liquid) |
| - polyethylene(resin pellets) | - ethanol amine(s)(simulated liquid) | - styrene(simulated liquid) |
| - ethylene dichloride(simulated liquid) | - glycol ethers(simulated liquid) | - polystyrene(resin pellets) |
| - vinyl chloride(simulated gas) | - vinyl acetate(simulated liquid) | |
| - polyvinyl chloride(resin pellets) | - polyvinyl acetate(resin pellets) | |

- also have some commercial products around as examples of everyday polymers, for example: P26-P27);

- | | |
|--|---------------------------------------|
| - low density polyethylene(squeeze bottle) | - plexiglass |
| - PVC pipe and records or tiles | - polystyrene(styrofoam) |
| - polypropylene carpet and rope | - Butyl rubber rubber(inner tube) |
| - Saran wrap | - acrylic(pen holder or paper weight) |
| - Teflon stopcock | - polyester repair kit |
| | - polyester, Orlon, etc. fabrics |

- see Pages 26 and 27 for more examples.

Materials for Identification of Some Polymers—Lab P1

The following polymers should be obtained in pellet form. Only one pellet is required per pair of students. 100-250 mL of pellets will last a long time. Obtain these pellets by one of the following ways:

1. have the school division or county buy large bags to share
2. beg or buy some pellets from the local institute of technology offering plastics courses.
3. ask chemical supply companies to start selling small quantities of pellets.

Pellets(resins) required:

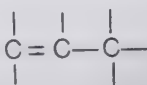

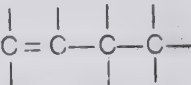
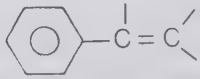
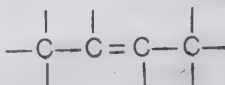
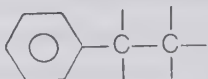
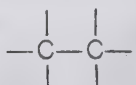
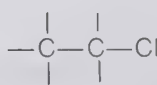
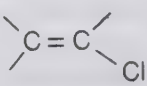
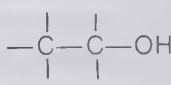
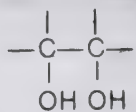
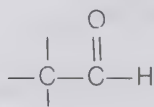
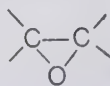
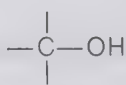
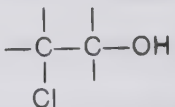
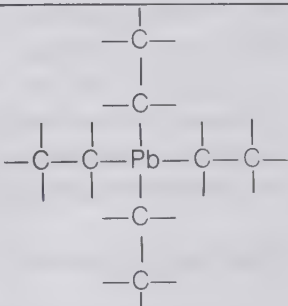
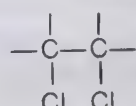
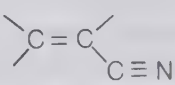
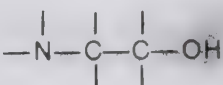
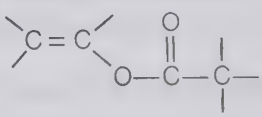

- | | |
|----------------------------------|----------------------------------|
| - polytetrafluoroethane(Teflon) | - polyester resin |
| - polyvinylidene chloride(Saran) | - acrylic resin |
| - polyvinyl chloride(PVC) | - low density polyethylene(LDP) |
| - Nylon 6—6 | - high density polyethylene(HDP) |
| - polystyrene(Styrofoam) | - polypropylene |
| - polyvinyl acetate(PVA) | |

Note: Lab P1 should be conducted in a well ventilated room.

ALCHEM ELECTIVES TEACHERS' GUIDE
ETHYLENE AND ITS DERIVATIVES

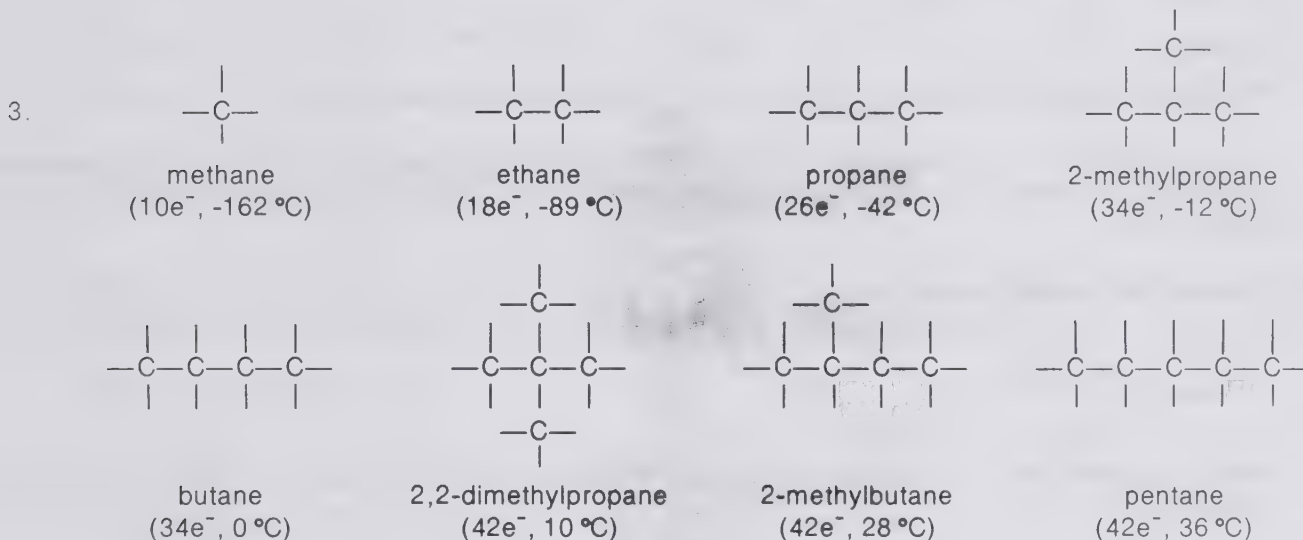
3

Pages P4-P5: Introduction

1.	propene	CH_2CHCH_3		11.	benzene	C_6H_6	
2.	1-butene	$\text{CH}_2\text{CHCH}_2\text{CH}_3$		12.	phenyl-ethene	$\text{C}_6\text{H}_5\text{CHCH}_2$	
3.	2-butene	$\text{CH}_3\text{CHCHCH}_3$		13.	phenyl-ethane	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$	
4.	ethane	CH_3CH_3		14.	chloroethane	$\text{CH}_3\text{CH}_2\text{Cl}$	
5.	chloroethene	CH_2CHCl		15.	ethanol	$\text{CH}_3\text{CH}_2\text{OH}$	
6.	1,2-ethanediol			16.			
7.				17.	methanol	CH_3OH	
8.		$\text{CH}_2\text{ClCH}_2\text{OH}$		18.	tetraethyl lead	$\text{Pb}(\text{CH}_3\text{CH}_2)_4$	
9.	1,2-dichloroethane			19.			
10.				20.			
				21.	methane	CH_4	

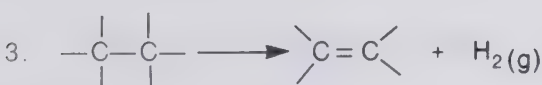
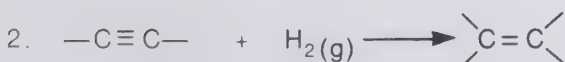
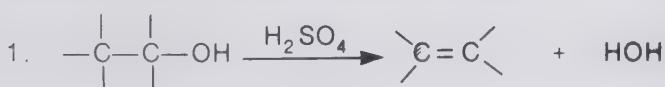
Page P12: Extraction, Distribution and Storage of Ethane

1. Fuel oil is extensively used for heating homes and other buildings in Ontario. (In Alberta natural gas is used for heating.)
2. Alberta has a large supply of natural gas containing approximately ten percent ethane. Natural gas with the ethane removed is a logical choice for fuel instead of fuel oil. In addition Alberta lacks the markets for the naphtha by-products.



4. The important intermolecular force is London dispersion forces. London dispersion forces are affected by number of electrons and the shape of the molecule. (The force results from the simultaneous attraction of the electrons of one molecule by its' nuclei and by the neighboring molecules' nuclei. The number of electrons per molecule is listed in the answers for Question 3.) A comparison of number of electrons per molecule and boiling points (see answers for Question 3) shows an increase in boiling point with an increase in the number of electrons per molecule. The boiling points of isoelectronic species varies due to the shape of the molecules. (See ALCHEM Unit G, *Chemical Bonding*.)
5. carbon dioxide, nitrogen and some ethane (see Table P1)
6. 93 % } - ignoring removal of propane—plus
7. 75 % } - percentage yield increases as percent of ethane in natural gas increases
8. A saturated salt solution keeps the cavern about the same size and shape. The oil makes double sure that top of the tear-drop shaped cavern remains pointed to prevent cave-ins.

Pages P15-P16: Production of Ethylene

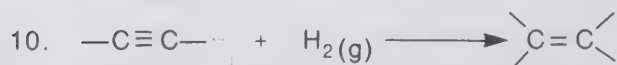
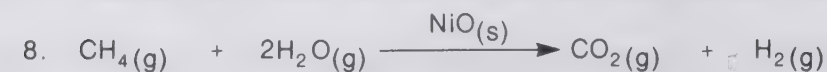


4. +87.9 kJ/mol

5. -174.6 kJ/mol

6. +136.9 kJ/mol

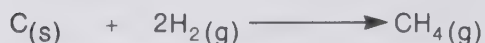
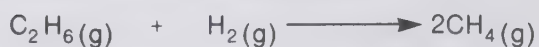
7. The ethane cracker operates at high temperature (800 °C) and low pressure (1 to 2 atmospheres), because the reaction is endothermic and produces two moles of gas for every one mole consumed. According to LeChatelier's Principle the reaction to the right will be favored at high temperature and low pressure. The reaction to the right will tend to reduce the temperature and increase the pressure.



(The same reaction was used during World War II to produce ethylene.)

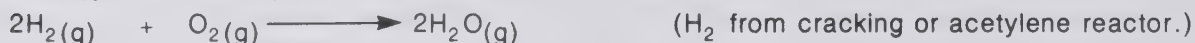
11. The boiling points of acetylene and ethylene are not sufficiently far apart to warrant a physical separation. (In addition the presence of appreciable amounts of ethane complicates any possible separation based on boiling points.)

12. Some possible reactions are:



(Many more reactions are possible. A more detailed study would involve activation energies and collision orientations.)

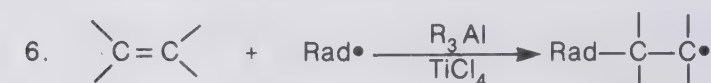
13. Possible reactions will be combustion reactions. For example:



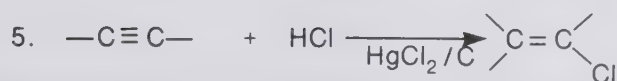
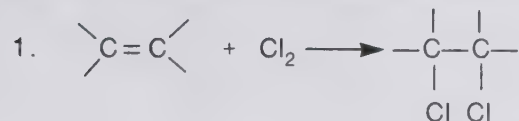
Page P21: Polyethylene



3. The decomposition reaction is explosive because of the hydrogen gas produced under high pressure.
4. Low density polyethylene contains polymer molecules with many side branches and it is produced by a free radical polymerization. High density polyethylene is the result of less branching in the molecules and can be produced by an ionic polymerization.
5. The more compact molecular shape (due to fewer branches) of the polymer molecules allows for closer packing of the molecules. London Dispersion forces are stronger when the molecules are closer together.

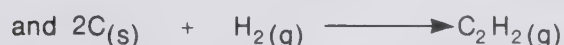
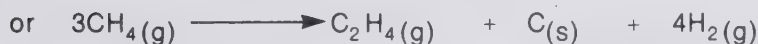
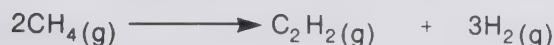


Page P22: Vinyl Chloride (History)



6. Alberta has a plentiful supply of lime (CaO) and coke (C). The HCl can be obtained by the reaction of H₂ (produced from natural gas) and Cl₂ (produced by electrolysis of salt)

7. Some possible reactions are:

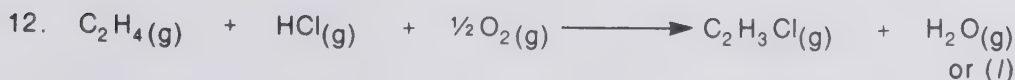
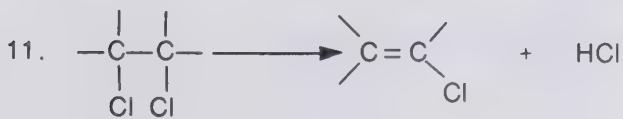
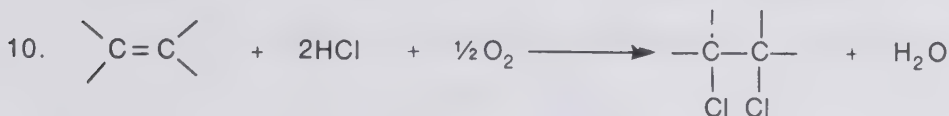


Note: Activation energies (collision energies) would have to be known to predict the most likely reactions.

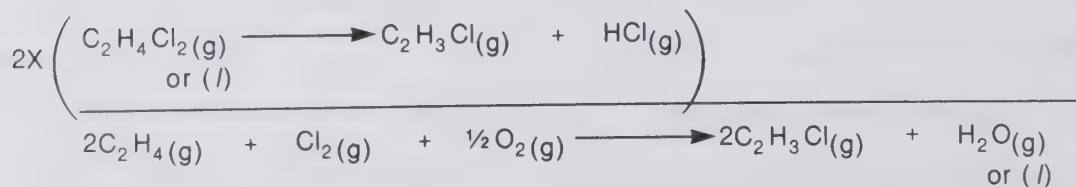
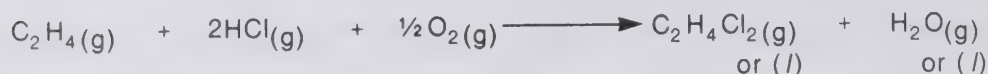
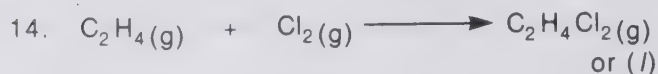
Pages P23-P24: Vinyl Chloride (Processes)



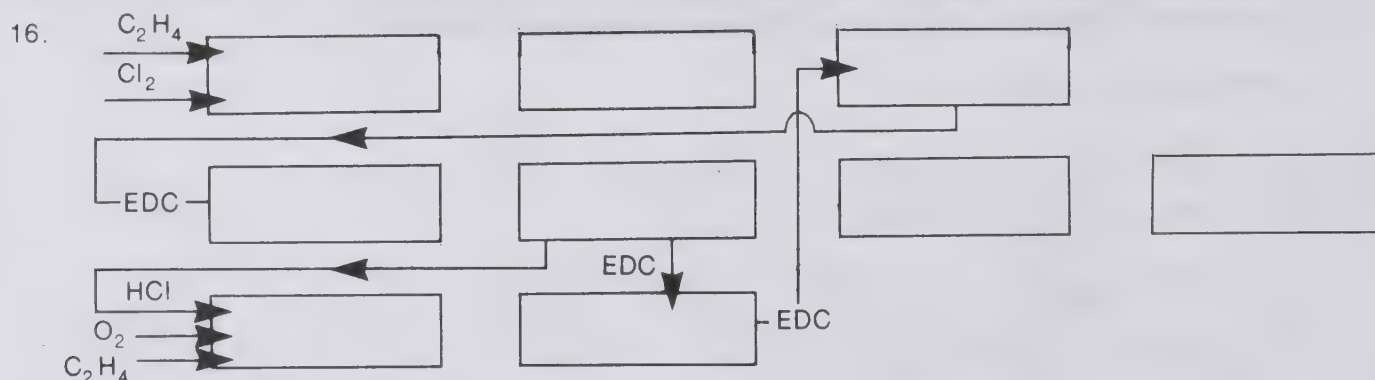
9. An addition reaction of chlorine and ethylene would be a problem. (see Question 1, page P22) Also, the HCl must be marketed or disposed of.



13. The only by-product is water. However., HCl is now required as a reactant. Oxygen must be obtained from the air or from a liquid-air plant.



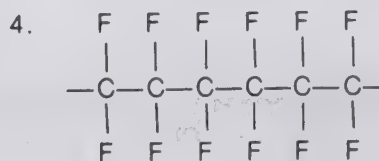
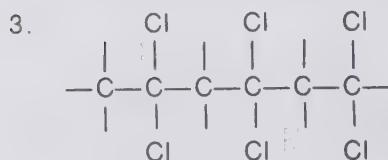
15. Chlorine, in addition to being a cheaper reactant than HCl, is readily available from the Dow chlor-alkali plant. In the two step process the HCl would have to be made separately or shipped in.

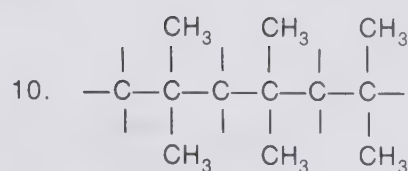
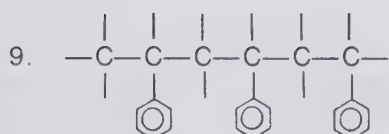
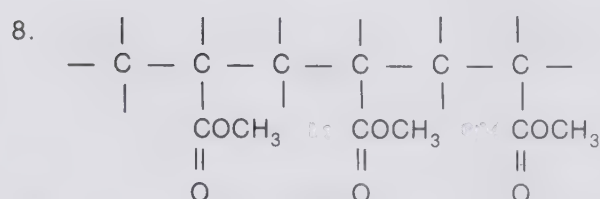
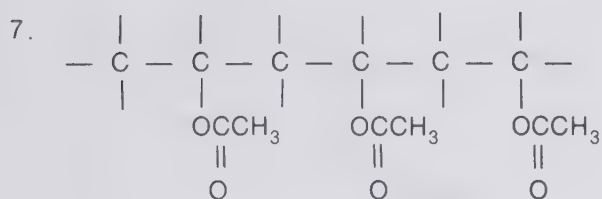
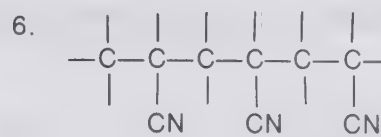
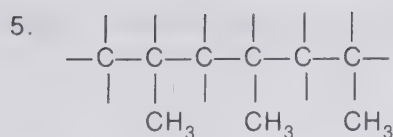


17. -111.0 kJ/mol (Use the equation from Question 8.)
 18. -167.8 kJ/mol (Use the equation from Question 12.)
 19. -139.4 kJ/mol (Use heats of formation and the net equation from Question 14.)

Pages P27-P28: Polyvinyl Chloride

1. Empirically determined means to be determined by experiment or experience (not by theoretical considerations).





Pages P29-P31: Identification of Some Polymers - Lab P1

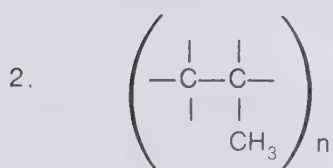
Prelab Exercise:

- A - polyvinylidene chloride
B - Nylon 6-6

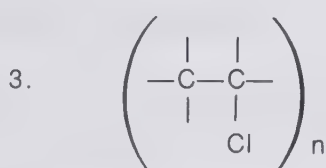
- C - polyvinyl acetate
D - acrylic resin

Questions:

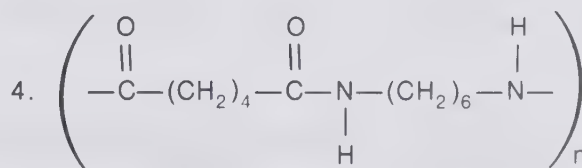
1. An accurate density determination could be done. If sufficiently large samples are available the hardness and flexibility of each should distinguish between LDP (relatively soft and flexible) and HDP (relatively hard and rigid).



London dispersion forces

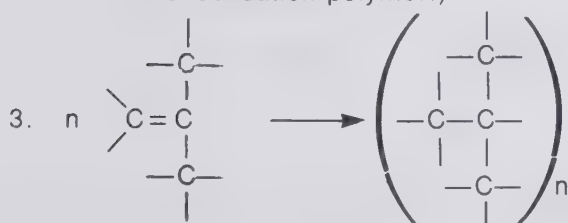


London dispersion forces
dipole-dipole forces

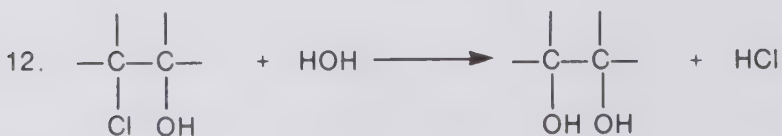
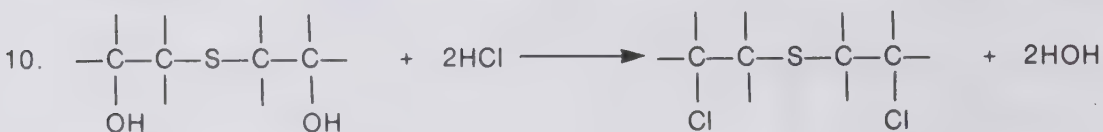
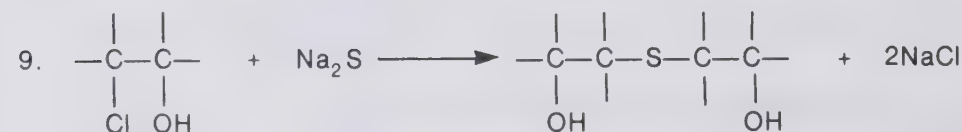
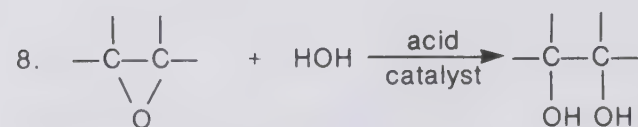
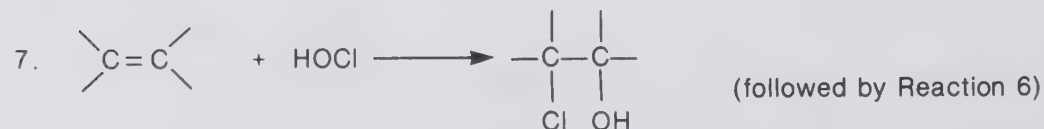
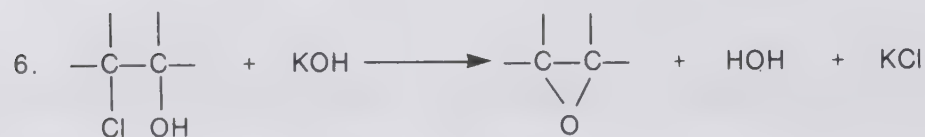
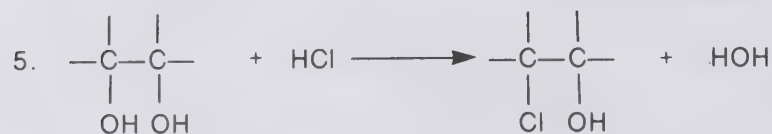
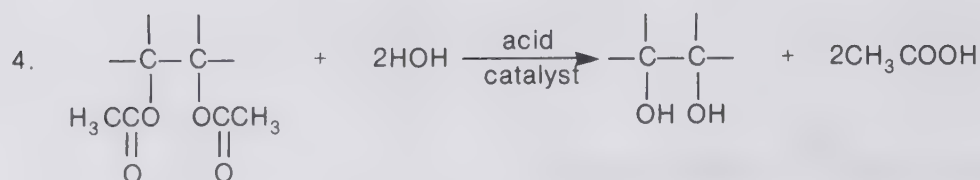
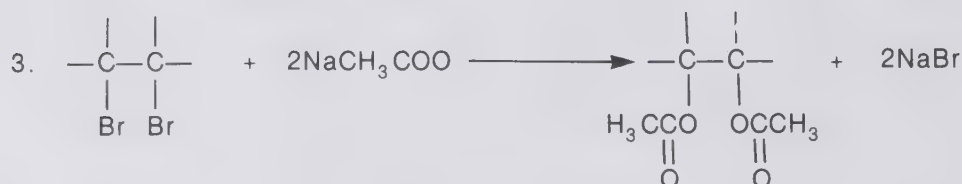
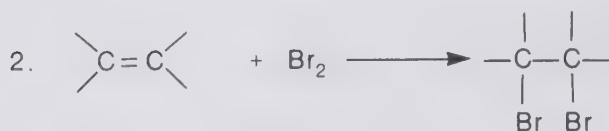
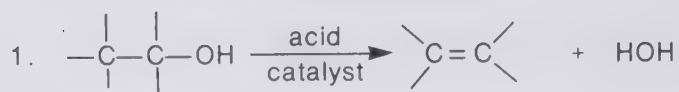


London dispersion forces
dipole-dipole forces
hydrogen bonding

Note: The same information can be obtained from the monomer structural formulas. (Nylon 6-6 is a condensation polymer.)



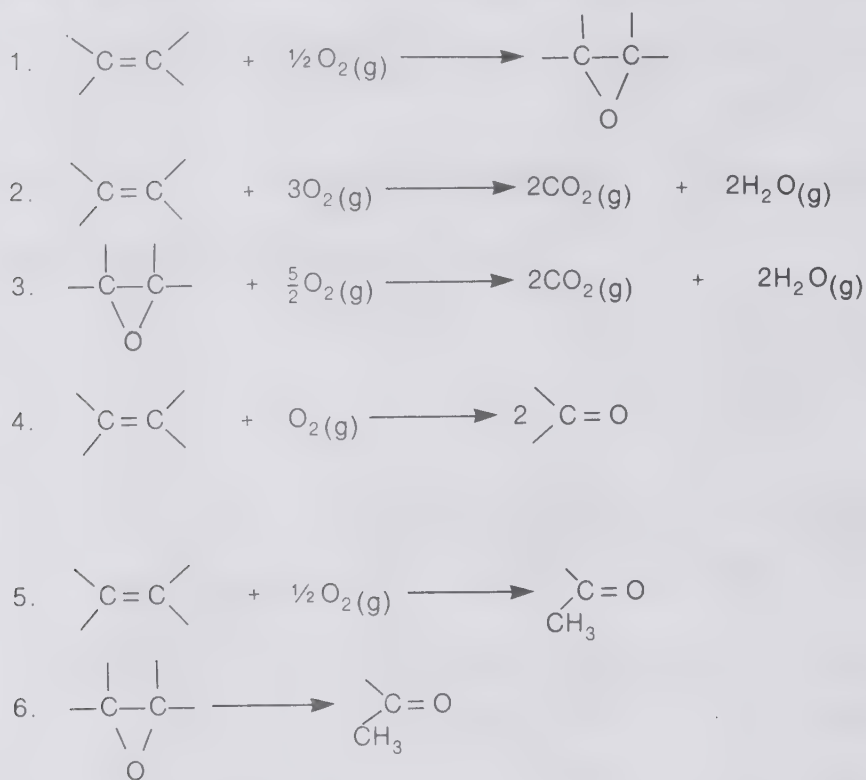
Pages P32-P34: History of Ethylene Oxide and Ethylene Glycol



Pages P34-P35: Industrial History of Ethylene Oxide and Derivatives

13. $\begin{array}{c} \diagup \quad \diagdown \\ \text{C}=\text{C} \\ \diagdown \quad \diagup \end{array} + \text{HOCl} \longrightarrow \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{Cl} & \text{OH} \end{array}$
 14. $2 \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{Cl} & \text{OH} \end{array} + \text{Ca(OH)}_2 \longrightarrow 2 \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} + \text{CaCl}_2 + 2\text{HOH}$
(CaCl_2 is used as a de-icer and wetting agent.)
 15. $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} + \text{HOH} \xrightarrow[\text{catalyst}]{\text{acid}} \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{OH} & \text{OH} \end{array}$
 16. $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{OH} & \text{OH} \end{array} + \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{OH} & \text{OH} \end{array} \xrightarrow[\text{catalyst}]{\text{acid}} \begin{array}{ccccc} | & | & & | & | \\ -\text{C} & -\text{C}- & \text{O}- & -\text{C} & -\text{C}- \\ | & | & & | & | \\ \text{OH} & & & \text{OH} & \text{OH} \end{array} + \text{HOH}$
 17. $\begin{array}{ccccc} | & | & & | & | \\ -\text{C} & -\text{C}- & \text{O}- & -\text{C} & -\text{C}- \\ | & | & & | & | \\ \text{OH} & & & \text{OH} & \text{OH} \end{array} + \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \\ \text{OH} & \text{OH} \end{array} \longrightarrow \begin{array}{ccccc} | & | & & | & | \\ -\text{C} & -\text{C}- & \text{O}- & -\text{C} & -\text{C}- & \text{O}- & -\text{C} & -\text{C}- \\ | & | & & | & | & & | & | \\ \text{OH} & & & \text{OH} & & & \text{OH} & \text{OH} \end{array} + \text{HOH}$
 18. $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} + \text{NH}_3 \longrightarrow \begin{array}{c} \text{H} \\ \diagdown \\ \text{N} \\ \diagup \\ \text{H} \end{array} - \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & | \\ & \text{OH} \end{array}$
 19. $\begin{array}{c} \text{H} \\ \diagdown \\ \text{N} \\ \diagup \\ \text{H} \end{array} - \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & | \\ & \text{OH} \end{array} + \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} \longrightarrow \begin{array}{ccccc} & & \text{H} & & \\ & & | & & \\ -\text{C} & -\text{C}- & \text{N} & -\text{C} & -\text{C}- \\ | & | & & | & | \\ \text{OH} & & & \text{OH} & \text{OH} \end{array}$
 20. $\begin{array}{ccccc} & & \text{H} & & \\ & & | & & \\ -\text{C} & -\text{C}- & \text{N} & -\text{C} & -\text{C}- \\ | & | & & | & | \\ \text{OH} & & & \text{OH} & \text{OH} \end{array} + \begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} \longrightarrow \begin{array}{ccccc} & & \text{H} & & \\ & & | & & \\ \text{HO}-\text{C} & -\text{C}- & \text{N} & -\text{C} & -\text{C}-\text{OH} \\ | & | & & | & | \\ \text{HO}-\text{C} & -\text{C}- & & & \end{array}$
 21. $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} + \begin{array}{c} | \\ -\text{C}-\text{OH} \end{array} \xrightarrow[\text{catalyst}]{\text{acid}} \text{HO}-\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & | \\ & \text{O}-\text{C}- \end{array}$
 22. $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & \diagup \text{O} \diagdown \end{array} + \begin{array}{cc} | & | \\ -\text{C} & -\text{C}-\text{OH} \end{array} \longrightarrow \text{HO}-\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ & | \\ & \text{O}-\text{C}-\text{C}- \end{array}$
- These reactions are similar to the reaction of ethylene oxide with water (H-OH).

Pages P36-P37: Production of Ethylene Oxide by Direct Oxidation



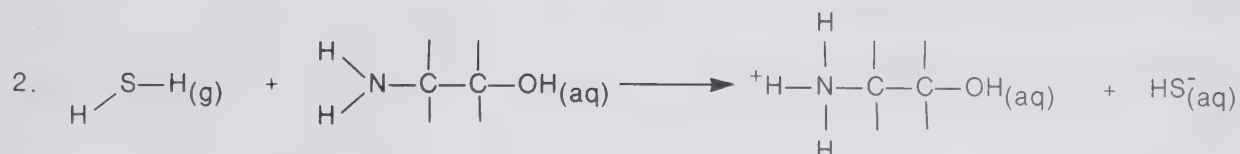
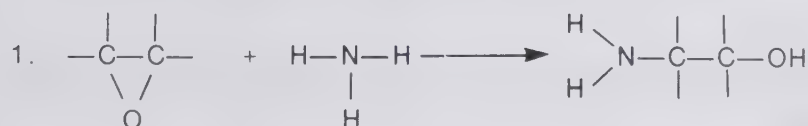
7. -103.4 kJ/mol

8. The exothermic production of ethylene oxide from ethylene results in an increased temperature which would increase the rate of reaction for the undesired reactions.

Pages P38-P39: Ethylene Oxide - Ethylene Glycol Plants

1. 212 Gg/a
2. The ethylene oxide molecule is polar and water may form hydrogen bonds with ethylene oxide resulting in a greater solubility (than C_2H_4 especially).
3. Increasing the temperature increases the rate of reaction.
4. An acid is used.
5. Ethylene glycols have greater London dispersion forces and have multiple hydrogen bonds.
6. $\text{TEG} > \text{DEG} > \text{MEG}$ due to the greater London dispersion forces and also the greater number of hydrogen bonds in the order given. (MEG 198 °C; DEG 245 °C; TEG 276 °C)
7. 319 kg/d (The reaction was considered in an historical context earlier.)
8. As the reaction proceeds MEG molecules may collide with MEG molecules to produce DEG. The greater the amount of water the less the number of MEG-MEG collisions, and the greater the number of EO- H_2O collisions per second.
9. A greater amount of water must be heated.
10. Economic factors and the market demand for the various ethylene glycols ultimately determine the ratio that is used.

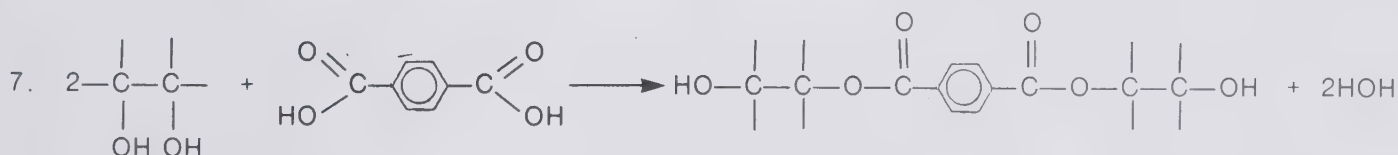
Pages P42-P43: Uses of Ethanolamines and Ethylene Glycols



4. DEA and TEA have greater solubility in water and have higher boiling points than MEA. When the H_2S is distilled off it is important that the DEA and TEA stay behind.

5. DEG and TEG will dissolve more water from the natural gas due to a greater number of possible hydrogen bonds.

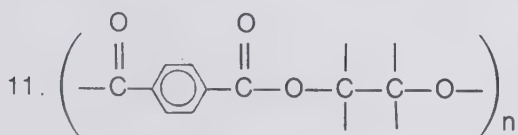
6. DEG is cheaper due to larger quantities being produced in glycol plants. (See Table P3.)



8. The removal of the water stops the reverse reaction (hydrolysis) and stops dilution (preventing a decreasing reaction rate).



10. No water is produced and the intermediate MEG need not be produced at a cost.



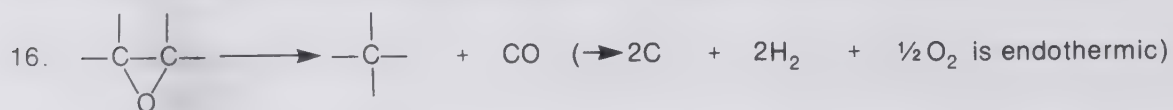
Dacron, Fortrel, Kodel, Terylene, Vycron

12. ethylene glycol, $HOCH_2CH_2OH$

13. When some of the water freezes the MEG % by volume increases and results in a lower freezing point solution.

14. a. When the temperature decreases to -30°C , some water freezes.
 b. The MEG % by volume increases.
 c. The freezing point of the solution decreases.
 d. Steps a, b & c continue until the temperature decreases to -48°C with an MEG % by volume of 56%.
 e. After -48°C , some more water freezes.
 f. The MEG % by volume increases.
 g. The freezing point of the solution *increases*.
 h. Steps e, f & g continue until all the water has frozen.
 i. The MEG then freezes.

15. Salts cause corrosion and alcohols evaporate away.



17. -161.9 kJ/mol

The Athabasca Tar Sands

The Athabasca Tar Sands

1

General Information

The Athabasca Tar Sands unit is an intermediate to senior level high school elective unit. The prerequisite knowledge and skills are listed in the introduction to the student materials. In general, students should have some background knowledge in gravimetric stoichiometry, solution chemistry, bonding and hydrocarbon chemistry. The Tar Sands unit may be done anytime after the above mentioned topics. Perhaps the best timing would be as an elective unit immediately following a core unit on organic chemistry or energy(thermochemistry).

The Tar Sands unit integrates the textual material, the exercises, a lab and a demo all in one package. The students keep the complete package when the unit is finished. The unit is not meant to be used for independent study unless supplemented by further explanatory material. Although no particular teaching method is dictated by the Tar Sands unit, the teacher's direction and assistance are required.

The Tar Sands unit may be seen as containing two types of materials. The first part of the unit is largely descriptive and contains very little chemistry related to chemical formulas and chemical reactions. The first part up to the Extraction of Bitumen lab should be moved through quickly. Student interest will be higher from the lab on to the end of the unit. As the end of the unit is approached frequent reviews of the entire process are recommended.

The amine scrubber and Claus converter are ancillary units to the direct line production of synthetic crude from tar sands. The sulfur produced is a by-product of tar sands upgrading. The amine scrubber and Claus converter used are essentially the same as those used for removing hydrogen sulfide from natural gas. Other ancillary units not covered in the unit are:

1. the burner(for heating coke and producing CO)
2. the CO boiler(for producing steam)

Future developments related to both tar sands and oil sands should be monitored through the local newspaper or oil industry magazines. New methods for refining tar sands are constantly being suggested and sometimes being piloted. Oil sands(heavy oil), such as found near Cold Lake, Alberta, will require different processing than described in this unit.

Lab Materials

The lab materials are listed in the student materials. The tar sand for the lab, along with bitumen for the demo and tailings sand for display are available from:

J.M. LeBel Enterprises Ltd.
10372 - 60 Avenue
Edmonton, Alberta
T6H 1G9

Synthetic crude is not available but may be simulated using a light automobile engine oil.

1. The local newspaper(usually the business section) and oil industry magazines should be monitored for articles related to tar sands and/or oil sands.
2. *Oil From The Tar Sands*, a junior to intermediate level general science unit available from Educational Services, Syncrude Canada, may be useful for producing overhead transparencies. This unit, which comes only as a teacher's edition, also contains a set of forty slides.
3. It is suggested that an overhead transparency be prepared from the flowchart contained herein. Frequent reviews of the flow charts with the students are recommended.
4. A Syncrude Canada, Athabasca tar sands wall flowchart is available from the publisher, J.M. LeBel Enterprises Ltd.
5. A set of slides to support the *Athabasca Tar Sands* unit is in the making and will be available from the publisher.

Prerequisite Knowledge and Skills

Before beginning the Athabasca Tar Sands unit students should be able to:

1. draw circle graphs
2. determine molar masses and do mass to moles and moles to mass calculations for a particular substance
3. determine the mass of one substance which would react with the given mass of another substance
4. follow lab instructions and work safely in the laboratory
5. use the like dissolves like rule to predict solubility of solutes in solvents
6. write Lewis(electron dot) diagrams
7. write structural formulas for aromatic and aliphatic hydrocarbons and compounds of sulfur, nitrogen and oxygen
8. write structural formulas for and recognize hydrocarbon isomers
9. write balanced chemical equations using structural formulas
10. predict reaction products for addition and substitution reactions
11. operate a bunsen burner and a centigram balance

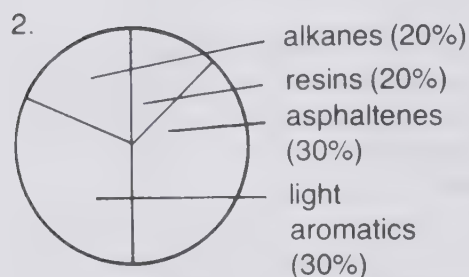
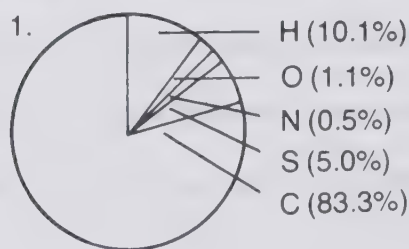
Unit Objectives

Upon completion of the Athabasca Tar Sands unit the student should be able to:

1. indicate the location, extent and importance of the Athabasca tar sands
2. describe the physical and chemical composition of tar sands
3. determine molecular formulas from percentage compositions
4. relate some of the history of the discovery of the Athabasca tar sands and of the development of commercial bitumen extraction processes
5. describe the extraction and treatment of bitumen froth to produce bitumen
6. list the variables which affect froth extraction
7. describe the coking of bitumen to produce lighter fractions
8. describe the changes that occur in molecular structure as a result of coking bitumen
9. describe the fractionating of coking products
10. list the possible fractions produced by the fractionators, and give reasons for producing the fractions
11. describe the hydrogenating process and write chemical equations for typical reactions which occur
12. describe the amine scrubber and Claus converter and write equations for the reactions which occur
13. describe the overall process used to produce synthetic crude from tar sands
14. appreciate the complexity of a major industrial process such as the production of synthetic crude from tar sands

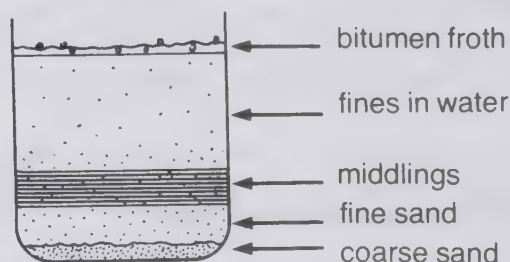
Answer Key

Pages 9-10 - Composition of Athabasca Deposit



3. 84.0 g C atoms
4. 10.1 g H atoms
5. 7.00 mol C atoms
6. 10.0 mol H atoms
7. C_7H_{10}
8. $C_{50}H_{71}$ ($C_{49.8}H_{71.2}$)
9. Bitumen consists of too great a variety of compounds with boiling points too close together for distillation into useful fractions.
10. V — 9.3×10^5 t or 0.93 Mt
Ni — 3.7×10^5 t or 0.37 Mt
Cu — 2×10^4 t or 0.02 Mt

Page 16 - Lab Observations: Part A



2. Emphasize the small yield (max. 12%) of bitumen from tar sands.


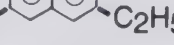
Page 17 - Lab Observations: Part B

Toluene and the hydrocarbon mixture (i.e., naphtha) will prove to be good solvents for bitumen.

Pages 18-19 - Lab Questions

1. pH = 8 to 9 (slightly basic)
2. a. bitumen adheres to the air bubbles and is carried to the top of the tank thereby assisting flotation
b. air bubbles agitate the mixture assisting separation
3. The finest particles are at the top of the sedimentary layer. Even finer particles are suspended in the water.
4. The unexpected difficulty of digging cold tar sand which was encountered by GCOS (the first large-scale commercial tar sands plant) might be mentioned.
5. The diluted bitumen from the centrifuge may be easily piped to the flash (naphtha recovery) tower (even in cold weather). The pure bitumen from the flash tower must be piped to the coker. The bitumen must be heated and the pipe heavily insulated. The closer that the flash tower is to the coker, the less expensive it is to heat the bitumen and insulate the pipe.
6. Toluene, c1ccccc1C, has both aliphatic and aromatic character (not unlike bitumen).
7. a. much cheaper
b. a hydrocarbon mixture as a solvent may be able to dissolve a greater variety of compounds.
8. a. pure bitumen is too viscous to ship via pipeline
b. diluted bitumen could be shipped via pipeline but a second (expensive) pipeline would then be required to return the naphtha diluent.

Pages 22-23 - Coking

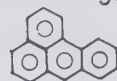
1. $C_{16}H_{10}$
2. 10, 12
3. 0.583 H/C, 302 g/mol
4. $C_{14}H_{10}$
5. 0.714 H/C
6. $C_{14}H_{30}$
7. 2.14 H/C
8. The alkane could be a straight chain, but it would most likely be branched.
9. C_3H_7 -- CH_3
 C_2H_5 -- C_2H_5 , 240 g/mol
10. 16
11. Yes, both are $C_{14}H_{10}$.
No, the structure is $C_{13}H_9$.
12. Note that each of these five isomers contain 3 and only 3 shared "sides". This is a quick check on other nonisomeric forms.



There are two isomers which contain 5 shared "sides";



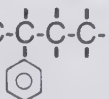

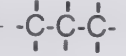
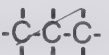

There is one other structure (to make 8 in total) which contains four aromatic rings (but 4 shared "sides");

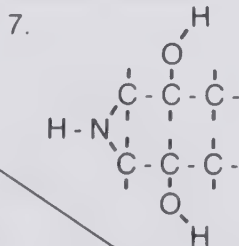


Page 26 - Demo

1. Commercial results are 10-20% solids, 72-79% liquids and 8-11% gases. Demo results will yield more solids and less liquids due to less than ideal conditions (largely determined empirically).
2. similar—heating without supply of air
different—hot coke is not the heat supply
—product gases are flared
—only two products from coker (coke and gases)
3. Use solvents to see if only some portions dissolve.
4. fractional distillation in a fractional distillation column or fractional condensation of high temperature gaseous products in different temperature water baths



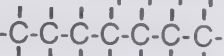
Pages 30-31 - Hydrotreating

1. $1 + 2 \rightarrow 1 +$ 
2. $1 + 3 \rightarrow 2 +$ 
3. $1 + 3 \rightarrow 2 +$ 
4. $1 + 4 \rightarrow 1 + 1 +$  + 



5. propane, C_3H_8 (g) (Also propane in Question 3 and butane in Question 2.)

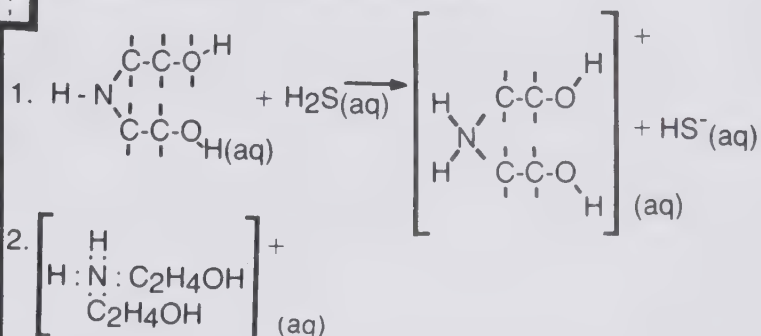
These new gases will mix with the H_2S (g), H_2O (g) and NH_3 (g) and be removed as gases to be treated in the amine scrubber.

6. $\text{C}=\text{C}-\text{C}=\text{C} + 2\text{H}-\text{H} \rightarrow$ 
7. - $CH_3 + 4\text{H}-\text{H} \rightarrow$ 
8. $C_9H_{11}ONS + 8H_2 \rightarrow H_2O + NH_3 + H_2S + C_9H_{20}(l)$
(g) (g) (g) (g)
9. consume: H_2 (g) 89.3 kg
produce: $H_2O(l)$ 99.4 kg H_2S (g) - 188 kg
 NH_3 (g) - 93.8 kg $C_9H_{20}(l)$ - 707 kg

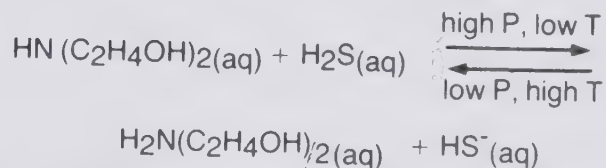
Pages 33 - Hydrogen Generator

1. $CH_4(g) + 2H_2O(g) \rightarrow 4H_2(g) + CO_2(g)$
 $C_2H_6(g) + 4H_2O(g) \rightarrow 7H_2(g) + 2CO_2(g)$
2. 455 kg + 47.1 kg = 502 kg

Pages 34-35 - Amine Scrubber



3. $H_2O(l)$ and $NH_3(aq)$ gain protons to form positive ions. $NH_3(aq)$ is most similar to DEA. The proton bonds to the lone (unshared) electron pair.
- 4.



5. Hydrogen bonding from OH groups ensures high solubilities in water for Reaction 1 and high boiling points for Reaction 2.
6. Ammonia is too volatile and would distill off with the H_2S (g) when the reaction in Question 4 is reversed.

Pages 36 - Claus Converters

1. $H_2S(g) + 3/2O_2(g) \rightarrow H_2O(g) + SO_2(g)$
2. $H_2S(g) + 1/2O_2(g) \rightarrow 1/2S_2(g) + H_2O(g)$
3. $2H_2S(g) + SO_2(g) \rightarrow 3/2S_2(g) + 2H_2O(g)$
4. 2:1, 1.06:1
5. 94.1%
6. 941 kg

Metallurgy and Corrosion

General Information

Unit T on metallurgy and corrosion is intended as an elective unit for ALCHEM 30, after the students have studied chemical energy and electrochemistry. This unit outlines the basic principles of metallurgy and describes the importance of the metals industry in Canada. The main causes of corrosion are outlined and several methods of corrosion prevention are described. The unifying thread is that metallurgy and corrosion are reverse processes. *Metallurgy* is the science of extracting a metal from its ore and *corrosion* is the return of the metal to its ore-like state. The emphasis in the unit is on applying chemical principles to practical situations. Three labs and two demos are included in the unit to illustrate the principles being discussed.

Audiovisuals

The following films/filmstrips fit in well with this unit.

1. Lead Matrix (American Society of Metals) - Color, 20 min
This film deals with the metallurgy of lead and the many uses of the element and its compounds. Available from the National Film Board.
2. Metal Crystals in Action (American Society of Metals) - Color, 28 min
The properties and composition of metals is explained in this film. The importance of metals is outlined and the formation and composition of alloys is discussed. Available from the University of Alberta Department of Extension.
3. Transformations: The Art, The Science, The Magic of Metallurgy
This record and filmstrip is available from Texasgulf.
4. Ascent of Man: The Hidden Structure - Color, 50 min (Part 1 and 2)
The history of the development of metallurgy and alloying is outlined. Part 1 is particularly relevant and may be shown without Part 2.

References

The following references give background information on metallurgy and corrosion which is helpful in teaching this unit.

1. "Corrosion - Part I" Chemistry, Jan.-Feb. 1976, pp. 14-16
- deals with the thermodynamics of corrosion
2. "Corrosion - Part II" Chemistry, June 1976, pp. 7-9
- deals with the mechanism of corrosion and the passivity of certain metals
3. "Corrosion - Part III" Chemistry, October 1976, pp. 10-12
- deals with methods of corrosion control
4. "Sir Humphry Davy's Battle with the Sea", Chemistry, September 1977, pp. 14-17
- outlines Davy's work during the 1820's to control corrosion in British ships
5. "Lab Bench: Investigating the Corrosion of Iron", Chemistry, September 1977, pp. 25-27
- outlines an experiment which shows some ways in which the corrosion of iron can be modified
6. "Rust and Your Car: What You Can Do", Readers' Digest, September 1977, pp. 67-71
- discusses causes of rusting in cars and suggests some ways to minimize it
7. Lowenheim, Fredrich, ed., Modern Electroplating, John Wiley, 1963

Lab Information

Demo T1 - Separation by Flotation

The following materials are required.

- 50 mL mineral oil
- 50 g sample of "crushed lead ore" (prepare this by mixing 10 g of $\text{PbO}_{(s)}$ with 40 g of sand)
- 1 - 150 x 25 mm test tube
- 1 - stopper to fit test tube
- 1 - test tube rack

Lab T1 - Roasting a Carbonate Ore

A lab of 16 stations will require the following materials.

- | | |
|--|-------------------------|
| - 300 g of $\text{CuCO}_{3(s)}$ or $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot \text{H}_2\text{O}_{(s)}$ | 16 - evaporating dishes |
| 16 - 10 cm iron rings | 16 - wire gauzes |
| 16 - ring stands | 16 - scoopulas |
| 16 - bunsen burners | 8 - balances |

Lab T2 - Reduction of a Metal (The use of the bunsen burner and blowpipe should first be demonstrated to the students.)

A lab of 16 stations will require the following materials.

- | | |
|----------------------------|-------------------------------------|
| - 300 g $\text{PbO}_{(s)}$ | 16 - 10 cm lengths of glass tubing |
| 16 - charcoal blocks | 16 - 20 cm lengths of rubber tubing |
| 16 - wire gauzes | 16 - flow pipes |
| 16 - 10 cm iron rings | 16 - bunsen burners |
| 16 - ring stands | 16 - scoopulas |

Lab T3 - Corrosion of Iron

A lab of 16 stations will require the following materials.

- | | |
|--|--|
| - 16 pieces of steel wool | 500 mL of distilled water |
| - 800 mL of acetone | 500 mL of deaerated water (freshly boiled) |
| 16 - 100 mL beakers | 100 mL of 0.01 mol/L $\text{CuSO}_4(aq)$ |
| 192 - 10 cm lengths of iron wire | 100 mL of 0.01 mol/L $\text{HCl}(aq)$ |
| 160 - 13 x 100 mm test tubes | 100 mL of 0.01 mol/L $\text{NaCl}(aq)$ |
| 32 - 18 x 150 mm test tubes | 100 mL of 0.01 mol/L $\text{NaOH}(aq)$ |
| 32 - rubber stoppers (to fit 18 x 150 mm test tubes) | 100 mL of 0.01 mol/L $\text{K}_2\text{Cr}_2\text{O}_7(aq)$ |
| 16 - test tube racks | |
| 16 - 10 cm lengths of magnesium ribbon | |
| 16 - 10 cm lengths of copper wire | |
| 16 - 2 cm lengths of transparent tape | |

Demo T2 - Prevention of Corrosion

The following materials are required.

- | | |
|---|--|
| 8 - 100 mL beakers | - 500 mL 0.01 mol/L $\text{NaCl}(aq)$ solution |
| 4 - 5 x 100 mm iron strips | - 80 mL conc. $\text{HNO}_3(aq)$ |
| 1 - 5 x 100 mm galvanized iron strip (use heating pipe or electroplate iron strips) | 3 - connecting c/w alligator clips |
| 1 - 5 x 100 mm tin-plated iron strip (use tin can strips or electroplate iron strips) | 1 - dry cell (1.5 V) |
| 1 - 5 x 100 mm painted iron strip | - 50 mL acetone |
| 1 - carbon rod | 1 - 10 cm strip of magnesium ribbon |

Answer Key

Page T2 - History of Metallurgy

1. Fe, Cu, Ag, Au, Hg, Sn, Pb, As, Sb
2. H, Y, Ti, Zr, Cr, Mo, W, Mn, Co, Ni, Pt, Zn, Bi
3. Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba, Ra, Sc, La, Ac, V, Nb, Ta, Ru, Os, Rh, Ir, Pd, Cd, Al, Ga, In, Tl, Ge, Po, Ce, Th, Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb
4. Fr, Hf, Rf, Ha, Te, Re, Pa, Pm, Np, Pu, Eu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lu, Lr
5. The less reactive metals(weak reducing agents) were discovered first as noble metals(i.e., Au, Ag, Fe, and Cu). In compound(ion) form these less reactive metals were strong oxidizing agents and were reduced (i.e., from the compound to the element) relatively easily in the charcoal and carbon monoxide in the fires of primitive peoples. The next large group of metals to be isolated were obtained mainly by electrolysis of aqueous solutions. The next advance was by Davy in 1807 with the electrolysis of metallic ions, which were weaker oxidizing agents than water, in molten state(i.e., Group IA and IIA).(Note the chronological progression down the Relative Strength of Oxidizing Agents table.)
6. Metallurgy is the science of extracting metals from their naturally occurring compounds and adapting these metals for the use of mankind.
7. Smelting is the process of extracting the metallic component of a compound by means of heating.
8. smelting of copper
production of bronze
production of steel

Page T3 - Metallurgy in Canada

1. aluminum 8.6×10^6 t
copper 8.1×10^6 t
iron 1.8×10^8 t
2. silver $\$1.47 \times 10^8$
molybdenum $\$6.35 \times 10^9$
zinc $\$9.59 \times 10^8$
3. galena 4.05×10^5 t
dolomite 3.42×10^5 t
pentlandite 1.11×10^6 t
4. 6.7 %

Page T6 - Separation by Flotation - Demo T1

Observations:

The yellow $\text{PbO}_{(s)}$ floats to the top of the mixture and is suspended in the "bubbly" mineral oil.

Question:

The mineral is less dense and finer(i.e., has larger surface area per mass unit) than the gangue(sand in this case) and thus tends to float easier and exert larger cohesive(interparticle) forces, respectively.

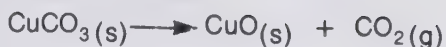
Pages T7-T8 - Roasting the Ore

1. $2\text{PbS}_{(s)} + 3\text{O}_{2(g)} \longrightarrow 2\text{PbO}_{(s)} + 2\text{SO}_{2(g)}$
2. $2\text{Ag}_2\text{S}_{(s)} + 3\text{O}_{2(g)} \longrightarrow 2\text{Ag}_2\text{O}_{(s)} + 2\text{SO}_{2(g)}$
3. $2\text{MoS}_{2(s)} + 7\text{O}_{2(g)} \longrightarrow 2\text{MoO}_{3(s)} + 4\text{SO}_{2(g)}$
4. $\text{MgCO}_{3(s)} \longrightarrow \text{MgO}_{(s)} + \text{CO}_{2(g)}$
5. $\text{ZnCO}_{3(s)} \longrightarrow \text{ZnO}_{(s)} + \text{CO}_{2(g)}$

6. 268 kg
7. -296.1 kJ/mol
8. +118.2 kJ/mol
9. -1117.7 kJ/mol
10. 649 kg

**Page T9 - Roasting a
Carbonate Ore - Lab T1**

Prelab Exercise:



Observations:

The copper mineral changes from a blue or green to a black oxide.

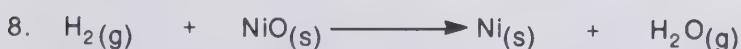
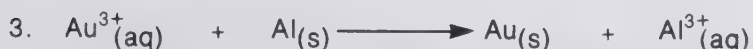
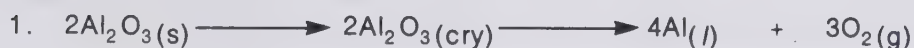
Questions:

1. The color change is due to the change from copper(II) carbonate(hydroxide) to copper(II) oxide.
2. The roasting of a sulfide ore produces sulfur dioxide, an irritating poisonous gas.
3. 0.665 g (from $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot \text{H}_2\text{O}(\text{s})$) or 0.719 g (from $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2(\text{s})$) or 0.644 g (from $\text{CuCO}_3(\text{s})$)
4. Yield will vary.

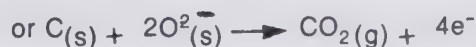
Page T11 - Reducing the Metal

1. 529 kg
2. 248 d
3. 889 kg

Pages T12-T13 - Reducing the Metal



To do by half-reactions use redox table plus:



11. 29.6 kJ/mol
12. 151.7 kJ/mol
13. -63.1 kJ/mol
14. -83.1 kJ/mol
15. -13.3 kJ/mol
16. -75.4 kJ/mol

Page T14 - Reduction of a Metal - Lab T2

Observations: The yellow $\text{PbO}_{(s)}$ becomes a molten globule of $\text{Pb}_{(l)}$.

Questions:

1. $\text{PbO}_{(s)} + \frac{1}{2}\text{C}_{(s)} \longrightarrow \text{Pb}_{(s)} + \frac{1}{2}\text{CO}_{2(g)}$, $H_{\text{Pb}} = +23.2 \text{ kJ/mol}$
2. Carbon monoxide produced by the partial combustion of the charcoal is likely another reducing agent.
3. 9.27 g

Page T15 - Overview of Extracting Metals from Ores

1. the process of treating the ore to remove gangue
2. placing the ore in a special furnace where it is heated in a plentiful supply of air
3. extracting the metallic component of a mineral as a free metal
4. removing undesirable impurities such as sulfur or carbon from the metal
5. a concentration process which separates the mineral particles from the gangue by bubbling air through a suspension of pulverized ore. The mineral particles are carried to the top by the froth.
6. the process of extracting the metallic component of a compound by heating
7. the impure metal coming from a smelter
8. use of an electrolytic cell to purify a metal. A slab of impure metal is placed at the anode and pure metal plates out at the cathode
9. chemical compounds which can be used as commercial sources of metals
10. the unusable rocky material associated with a valuable mineral
11. cathode: $2(\text{Ni}^{2+}_{(aq)} + 2e^{-} \longrightarrow \text{Ni}_{(s)})$
 anode: $2\text{H}_2\text{O}_{(l)} \longrightarrow 4e^{-} + \text{O}_{2(g)} + 4\text{H}^{+}_{(aq)}$
 net: $2\text{Ni}^{2+}_{(aq)} + 2\text{H}_2\text{O}_{(l)} \longrightarrow \text{O}_{2(g)} + 4\text{H}^{+}_{(aq)} + 2\text{Ni}_{(s)}$
12. Since water is a stronger oxidizing agent than some metallic ions such as the sodium ion, water would be reduced at the cathode rather than the metallic ion. Metallic ions such as the copper(II) ion are stronger oxidizing agents than water.

Page T17 - Alloys

1. Cu_3Al 87.6 % Cu, 12.4 % Al
 Cu_5Zn_8 37.8 % Cu, 62.2 % Zn
 Cu_2Mg 83.9 % Cu, 16.1 % Mg
2. Cu_5Sn
3. Sterling Silver, Brass, German Silver, Chrome Steel, Molybdenum Steel, Nickel Steel, Stainless Steel, Monel Metal
4. Woods Metal, Solder
5. Cast Iron, Chrome Steel, Molybdenum Steel, Nickel Steel, Manganese Steel

Page T19 - Corrosion

Assuming 5 s to read the poster, the amount of iron corroded in Canada is calculated by:

$$9.17 \times 10^6 \frac{\text{t}}{\text{a}} \times \frac{1 \text{ a}}{365 \text{ d}} \times \frac{1 \text{ d}}{24 \text{ h}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times 5 \text{ s} \times \frac{20}{100} = 0.3 \text{ t (or 6 t for the world.)}$$

Page T20 - Equations for Corrosion Reactions

1. $\text{Pb}_{(\text{s})} + 2\text{H}^+_{(\text{aq})} \longrightarrow \text{Pb}^{2+}_{(\text{aq})} + \text{H}_{2(\text{g})}$
2. $\text{Br}_{2(\text{g})} + \text{Ni}_{(\text{s})} \longrightarrow \text{NiBr}_{2(\text{s})}$
3. $\text{Mg}_{(\text{s})} + 2\text{H}_2\text{O}_{(\text{l})} \longrightarrow \text{Mg(OH)}_{(\text{s})} + \text{H}_{2(\text{g})}$
4. $2\text{Zn}_{(\text{s})} + \text{O}_{2(\text{g})} + 2\text{H}_2\text{O}_{(\text{l})} \longrightarrow 2\text{Zn(OH)}_{2(\text{s})}$
5. $\text{Cu}_{(\text{s})} + \text{H}_2\text{S}_{(\text{g})} \longrightarrow \text{CuS}_{(\text{s})} + \text{H}_{2(\text{g})}$

Page T22 - Corrosion of Iron - Lab T3

1. spontaneous reaction(see redox table)
2. spontaneous reaction(see redox table)
3. no rust (perhaps cleaner)(check acidity)
4. no reaction except at surface perhaps
5. no reaction (not acidic)(perhaps cleaner)
6. rust
7. unwrap to see rust
8. no reaction on iron
9. no reaction under tape
10. corrosion at bend
11. no reaction (acidic solution may clean)
12. no reaction

Questions:

1. $\text{CuSO}_4_{(\text{aq})}$
2. dry air
3. distilled water

Page T24 - Corrosion of Iron

1. Step 1: $4\text{Fe}_{(\text{s})} \longrightarrow \text{Fe}^{2+}_{(\text{aq})} + 2\text{e}^-$
Step 2: $8\text{H}^+_{(\text{aq})} + \text{e}^- \longrightarrow \text{H}_{(\text{aq})}$
Step 3: $2(4\text{H}_{(\text{aq})} + \text{O}_{2(\text{g})} \longrightarrow 2\text{H}_2\text{O}_{(\text{l})})$
Step 4: $4\text{Fe}^{2+}_{(\text{aq})} + \text{O}_{2(\text{g})} + 10\text{H}_2\text{O}_{(\text{l})} \longrightarrow 2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}_{(\text{s})} + 8\text{H}^+_{(\text{aq})}$
Overall: $4\text{Fe}_{(\text{s})} + 3\text{O}_{2(\text{g})} + 6\text{H}_2\text{O}_{(\text{l})} \longrightarrow 2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}_{(\text{s})}$

2. Aqueous sodium chloride is an electrolyte which can act as a charge carrier accelerating some of the steps in the reaction mechanism for the corrosion of iron.
3. Two different metals in contact with each other and the same electrolyte will undergo a spontaneous redox reaction. The copper pipe and the iron straps will corrode when water vapor condenses on them.
4. The iron atoms are oxidized to iron(II) ions. The rust does not form until the iron(II) ions migrate to the surface where they come in contact with oxygen. The rust forms a protective layer on the iron preventing pitting above the water-line. The unprotected iron below the water-line pits badly.

Page T28 - Protective Coatings

1. The chloride ion from table salt disrupts the crystalline continuity between the aluminum and its protective layer of aluminum oxide.
2.
$$\text{Cu(s)} + \text{CO}_2(\text{g}) + \text{H}_2\text{O(l)} \longrightarrow \text{H}_2(\text{g}) + \text{CuCO}_3(\text{s})$$

$$\text{Cu(s)} + 2\text{H}_2\text{O(l)} \longrightarrow \text{H}_2(\text{g}) + \text{Cu(OH)}_2(\text{s})$$

 The simultaneous formation of $\text{CuCO}_3(\text{s})$ and $\text{Cu(OH)}_2(\text{s})$ gives the basic carbonate, $\text{CuCO}_3 \cdot \text{Cu(OH)}_2(\text{s})$.
3. The following chemical species (all present in commercial gun bluing) are listed as oxidizing agents on the ALCHEM data sheet: $\text{Hg}^{2+}(\text{aq})$, $\text{Fe}^{3+}(\text{aq})$, $\text{Cu}^{2+}(\text{aq})$, $\text{H}_2\text{O(l)}$, $\text{NO}_3^-(\text{aq})$. Although not listed in the ALCHEM data sheet, $\text{ClO}_3^-(\text{aq})$ and $\text{C}_2\text{H}_5\text{NO}_2(\text{aq})$ are oxidizing agents as well. The oxidizing agents present in the gun bluing form a thick passive coating of Fe_3O_4 which prevents further oxidation.
4. When the tin coating on the can is broken the underlying steel rusts rapidly because of the "electrochemical cell effect" (two different metals joined to each other and in contact with the same electrolyte act like an electrochemical cell). The aluminum is protected by a tightly adhering film of aluminum oxide. If the oxide layer is broken a new one forms to take its place.

Page T31 - Cathodic Protection

1. The area of the cathode, the resistance of the ground, the metal being protected, the oxidizing agents present.
2. anode:
$$2(\text{Zn(s)} \longrightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-)$$

 cathode:
$$\text{O}_2(\text{g}) + 2\text{H}_2\text{O(l)} + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$$

 overall:
$$2\text{Zn(s)} + \text{O}_2(\text{g}) + 2\text{H}_2\text{O(l)} \longrightarrow 2\text{Zn(OH)}_2(\text{s})$$
3. To protect the large surface area of a steel tank or pipe from corrosion huge currents would be needed. It is more economical to apply a reasonably good protective coating and then employ a relatively small current to prevent corrosion at the points where the surface coating is damaged.
4. 15 mA

Pages T33-T36 - Overview

1. Fe, Cu, Ag, Au, Hg, Sn, Pb, Sb
 These were the first metals isolated because they can be easily reduced from their ores.
2. Copper and tin are easier to smelt than is iron, therefore methods of working bronze (a copper-tin alloy) were developed before methods of smelting and working iron.
3.
$$\text{HgS(s)} + \text{O}_2(\text{g}) \longrightarrow \text{Hg(l)} + \text{SO}_2(\text{g})$$

$$2\text{Hg(l)} + \text{O}_2(\text{g}) \longrightarrow 2\text{HgO(s)}$$

$$2\text{HgO(s)} \longrightarrow 2\text{Hg(l)} + \text{O}_2(\text{g})$$
4. chalcopryite (CuFeS_2), galena (PbS), pentandite ($\text{NiS} \cdot 2\text{FeS}$), argentite (Ag_2S), molybdenite (MoS_2), sphalerite (ZnS). The sulfide ores are roasted to produce the oxide of the metal.
5. Mineral particles attach themselves to the bubbles of a froth made by bubbling air up through a cell containing a water suspension of the ore.

6. 657 kg
7. 91.7 g
8. 68.8 kg
9. 1.12 kg
10. 3.2 Ms or 37 d
11. A slab of the impure metal is used as the anode in an electrolytic cell. Pure metal plates out at the cathode.
12. solid solution, heterogenous mixture and intermetallic compound
13. Alloys generally are harder and more resistant to corrosion than pure metals. Alloys generally have higher melting points and higher electrical resistance than their components.
14. $\text{HgCl}_2(\text{aq}) + \text{Fe}(\text{s}) \longrightarrow \text{FeCl}_2(\text{aq}) + \text{Hg}(\text{l})$
15. $\text{Pb}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \longrightarrow \text{Pb}(\text{OH})_2(\text{s}) + \text{H}_2(\text{g})$
 $\text{Pb}(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \longrightarrow \text{PbCO}_3(\text{s}) + \text{H}_2(\text{g})$
 $\text{Pb}(\text{OH})_2(\text{s}) + \text{PbCO}_3(\text{s}) \longrightarrow \text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$
16. $2\text{Fe}(\text{s}) + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \longrightarrow 2\text{Fe}(\text{OH})_2(\text{s})$
17. $\text{Fe}(\text{s}) + \text{H}_2\text{S}(\text{g}) \longrightarrow \text{FeS}(\text{s}) + \text{H}_2(\text{g})$
18. $\text{Cu}(\text{s}) + \text{Cl}_2(\text{g}) \longrightarrow \text{CuCl}_2(\text{s})$
19. Gold and silver are resistant to corrosion. Plating cheap metals with silver or gold protect the cheaper metal from corrosion as well as giving them an attractive lustre.
20. When the silver plate wears off a silver plated spoon the underlying metal is exposed. When the spoon is placed in an electrolytic solution (like an acidic food) the "electrochemical cell effect" causes corrosion of the underlying metal.
21. Treating iron with strong oxidizing agents can form hard adherent layers of $\text{Fe}_3\text{O}_4(\text{s})$ which resist further corrosion.
22. The metal to be protected is supplied with electrons from an external source. The supply of electrons makes the metal cathodic and prevents its oxidation.
23. A sacrificial anode is made of a metal which is more easily oxidized than the one to be protected. The more active metal oxidizes and supplies electrons (by means of a wire) to the metal to be protected.
24. No. For this to work, both metals must be in contact with the same electrolyte.

Nuclear Chemistry

General Information

Information about Nuclear Energy

Atomic Energy of Canada Limited has a toll-free telephone number (ZE07444) to the Whiteshell Nuclear Research Establishment at Pinawa, Manitoba. Calls will be answered weekdays between 8 15 and 16 30 (Manitoba time). Dial the long distance operator and ask for the operator to dial the number. This excellent service will provide answers to questions on all aspects of nuclear energy in Canada. Questions will be answered either immediately or by information sent by mail. In addition to publications, posters and class sets of the Layman's Guides are also available free of charge.

The following book gives a good account of the development of nuclear energy in Canada:

Eggleston, Wilfred, Canada's Nuclear Story, Clarke Irwin and Co. Limited, Toronto and Vancouver.

Information on Isotopes

1. Weast, Robert, C, (ed), CRC Handbook of Chemistry and Physics, The Chemical Rubber Co., 18901 Cranwood Parkway, Cleveland, Ohio, 44128.

Data on all the currently known stable and radioactive isotopes are included in the section on isotopes.

2. Chart of the Nuclides, available from General Electric Company, 1 River Road, Schenectady, New York, 12345.

An excellent wall chart which includes all of the information given in the CRC Handbook of Chemistry and Physics plus information on fission products and yields of Pu-239 and U-235 fission and production of trans-uranium elements.

Films

The following film is distributed by International Telefilm Enterprises, 47 Densley Avenue, Toronto, Ontario, M6M 5A8.

1. "The Origin of the Elements", 18 min, color

The evolution of the elements by nuclear fusion reactions is related to the evolution of the stars. The alpha, proton (p), slow (s) and rapid (r) processes are discussed. A teacher's guide is included.

The following films are available through the National Film Board.

2. "This Nuclear Age", min, color

This film presents a general review of Canada's progress and achievements in the development of peaceful uses of atomic energy.

3. "Atomic Energy in Canada", 27 min

The story of Chalk River Nuclear Laboratories is presented. The film also describes how nuclear energy makes electricity and the production of radioisotopes.

4. "Douglas Point - Nuclear Power Station"

This film follows the construction of Canada's first full-scale nuclear power station from the initial blasting for the excavation to the completion of the project.

5. "On the Critical Path", 22 min

This film deals with the highly successful Pickering Generating Station.

6. "On Power Refueling", 13 min

Refueling of the CANDU reactors at the Pickering station is described in detail.

7. "Radiation", 26 min

This film describes how radiation affects every form of life.

8. "Radioisotopes, Tools of Discovery"

This film deals with the applications of radioisotopes.

ALCHEM ELECTIVES TEACHERS' GUIDE

NUCLEAR CHEMISTRY

Other Audio-Visual Material

1. Minicourses (individual study projects) on Nuclear Energy

The Nuclear Energy Series was written with the assistance of AECL and consists of four programs. Each program includes a study guide, set of review sheets, instructor's guide and an audiotape. Class sets are also available.

- | | |
|-----------|---|
| Program 1 | An Introduction to Radioactivity (includes a student cloud chamber and radioactive sources) |
| Program 2 | Energy from the Nucleus |
| Program 3 | Rutherford and Fermi: Papa and the Pope |
| Program 4 | Nuclear Energy and Society |

Available from: Merlan Scientific
P.O. Box 208
Port Credit, Ontario,
L5G 4L7

2. Nuclear Science and Technology Resource Kit. This kit is produced by Ontario Hydro and includes film-strips, cassette tapes, review sheets and a teachers' guide.

- | | |
|-------------|--|
| Program I | Nuclear Basics |
| Program II | A Visit to a Nuclear Reactor |
| Program III | More than Meets the Eye (CANDU Fuel Cycle) |
| Program IV | Nuclear Energy and Your Health |

Write to: Energy Education, H10-G1,
Ontario Hydro,
700 University Avenue,
Toronto, Ontario
M5G 1X6

3. Nuclear Energy Slide Talk, 35 mm, color slides (70) with a 22-page text.

Canadian Nuclear Association,
Suite 1120,
66 Queen St., West,
Toronto, Ontario
M5H 2M5

Detecting Radioactivity - Demo U1 (Pages 3-4)

Notes:

1. The radioactive sources are normally mounted on the heads of needles which are embedded in rubber stoppers. The alpha source normally contains radium and the beta-negative source contains strontium-90. The isotope sources usually contain cobalt-60 and sodium-22. The amount of radioactivity produced is extremely small and the sources are very safe. However, wash hands carefully if sources are accidentally handled.
2. Dry ice may be obtained at the nearest university or dairy.
3. Cloud chambers must be thoroughly cleaned to function properly.
4. If student cloud chambers and sources are available, Part A could be done as a student lab and Part B as a demo.

Page U2: Nuclear Radiation and Nuclear Particles

1. To fluoresce means to absorb radiation (X-rays, ultraviolet, etc.) and to re-emit different radiation (usually visible light).
2. Radioactivity is the spontaneous emission of nuclear particles or radiation by a substance.
3. Isotopes are atoms that have the same number of protons but different numbers of neutrons.
4. Radioisotope is an isotope which is also radioactive.
5. Transmutation is the process by which one element is changed into another element.

Page U4: Detecting Radioactivity - Demo U1

Questions:

1. Background radiation is the sum of all the natural radiation (cosmic rays, radioactive elements in the earth, etc.) that is normally present at a particular location.
2. The source of background radiation is normally cosmic rays which come from outer space (particularly from the sun). A cloud chamber or a Geiger counter may be used to demonstrate the existence of this background radiation.
3. Condensation nuclei are particles that serve as starting points for the growth of visible droplets in a vapor or liquid. Water droplets in clouds and rain form as the result of dust particles acting as condensation nuclei. (Cloud seeding is man's attempt to produce rain by supplying condensation nuclei.)
4. All of the charged particles (alpha, beta and proton) would be directly visible because they are charged. Neutrons and gamma rays carry no electric charge and therefore would not be directly detected. (Secondary effects producing charged particles can be observed.)
5. All of the radiations should be detectable because a Geiger counter detects the ions and electrons produced as the result of the interactions of the radiation and gas molecules in the Geiger tube.
6. (Optional) Alpha particles carry twice the electric charge of a beta particle and therefore the effect on the vapor is exerted over a greater distance. The mass of an alpha particle is much greater so that, for a given energy, their speed is much lower. (In general, the density of ionization is proportional to the square of the charge of the particle and inversely to the square of the speed.)
7. (Optional) The vapor trail could correspond to an alpha particle or proton colliding with a gas atom and producing two charged particles. (Nuclear interactions like these are very rarely seen in a cloud chamber under ordinary conditions.)

Page U5: The Nuclear Atom

1. When Rutherford "fired" his "atomic bullets" (alpha particles) at an extremely thin metal foil 99 % of them passed directly through the foil. The very few alpha particles that were reflected almost straight back was totally unexpected.
2. The boundary of the atom would be at about the goal line.

Page U8: Structure of Isotopes

	Name	Isotope Notation	Atomic Number	Mass Number	Subatomic Particles			Net Charge On Species
					Protons	Neutrons	Electrons	
1.	fluorine atom		9	19	9	10	9	0
2.		$^{65}_{30}\text{Zn}$	30	65	30	35	30	0
3.	potassium atom	$^{39}_{19}\text{K}$	19	39				0
4.	potassium ion	$^{40}_{19}\text{K}^{+}$	19	40				1+
5.		$^{31}_{15}\text{P}$	15	31	15		15	0
6.	copper atom		29	63	29	34	29	0
7.	iron atom	$^{56}_{26}\text{Fe}$	26		26	30	26	0
8.	uranium atom	$^{235}_{92}\text{U}$			92	143	92	
9.		$^{238}_{92}\text{U}$	92		92	146	92	0
10.	magnesium ion	$^{26}_{12}\text{Mg}^{2+}$	12	26				2+
11.		$^{37}_{17}\text{Cl}^{-}$	17	37	17		18	1-
12.		$^{35}_{17}\text{Cl}^{-}$	17		17	18	18	1-
13.	strontium atom		38	90	38	52	38	0
14.	aluminum ion	$^{27}_{13}\text{Al}^{3+}$	13	27				3+

Page U12: Stability of Nuclei

1. Nuclear binding energy is the energy released when a nucleus is formed from its component nucleons.
2. The greater the binding energy per nucleon the more difficult it is to pull the nucleons, and thus the nucleus, apart.
3. Nuclei of elements with the smallest and largest mass numbers are less stable than nuclei of elements with intermediate mass numbers (40-60).
4. Unstable nuclei would be those with too many neutrons (above the graph), too many protons (below the graph) or a mass number greater than 83.
5. $^{202}_{85}\text{At}$ - Z greater than 83, odd numbers of p and n
6. $^{146}_{55}\text{Cs}$ - n/p ratio is too high (too many neutrons), odd numbers of p and n
7. $^{212}_{86}\text{Rn}$ - Z greater than 83
8. $^{39}_{20}\text{Ca}$ - n/p ratio is too low (too many protons), odd number of n
9. $^{20}_{20}\text{Ca}$ stable: e-e, e-e, e-o, e-e, e-e, e-e
 unstable: e-o, e-e, e-o, e-o, e-o, e-o, e-o, e-e
- $^{19}_{19}\text{K}$ stable: o-e, o-e
 unstable: o-o, o-e, o-o, o-o, o-o, o-e, o-o, o-e, o-o, o-e
- $^{12}_{12}\text{Mg}$ stable: e-e, e-o, e-e
 unstable: e-o, e-e, e-o, e-o, e-e, e-o, e-e
- $^{13}_{13}\text{Al}$ stable: o-e
 unstable: o-e, o-o, o-e, o-o, o-o, o-e, o-o, o-e, o-o, o-e
- $^{14}_{14}\text{Si}$ stable: e-e, e-o, e-e
 unstable: e-o, e-e, e-o, e-o, e-e, e-o, e-e, e-o, e-e

The greatest number of stable nuclei have an even number of protons and neutrons. The majority of unstable nuclei have an odd number of protons and/or neutrons.

10. Calcium nuclei have an even number of protons and a relatively high binding energy per nucleon. (See Figure U2)
11. An acceptable model must account for experimental observations and predict the results of further experiments or observations.

Page U13: Nuclear Equations

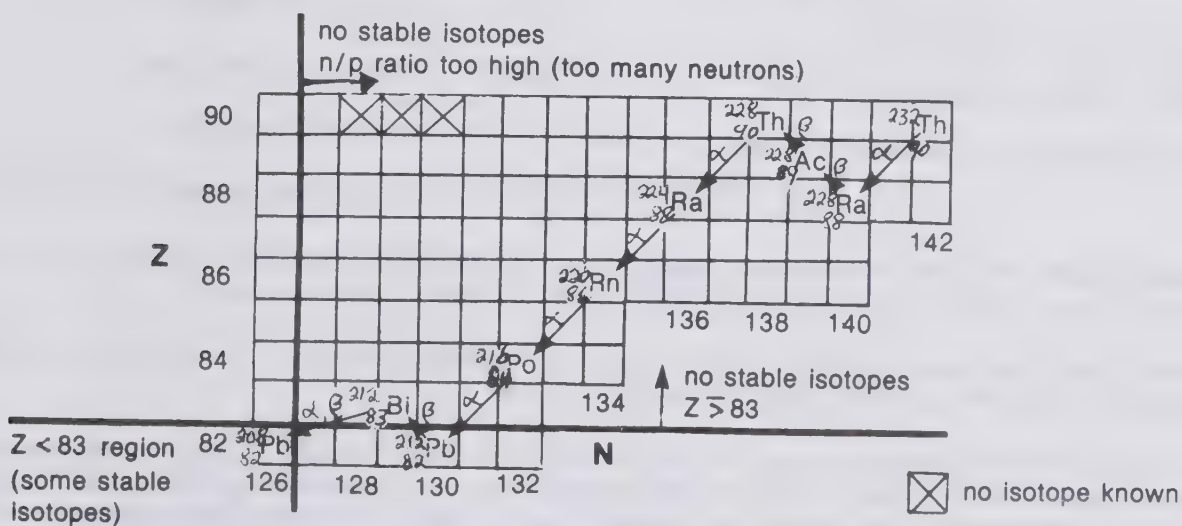
- | | | |
|---------------------------|---------------------------|---------------------------|
| 1. $^0_1\beta$ | 5. $^0_1\beta$ | 9. $^{226}_{88}\text{Ra}$ |
| 2. $^{206}_{81}\text{Tl}$ | 6. $^{53}_{25}\text{Mn}$ | 10. γ |
| 3. $^{17}_8\text{O}$ | 7. $^{250}_{98}\text{Cf}$ | 11. $^{235}_{92}\text{U}$ |
| 4. $^{11}_6\text{C}$ | 8. ^3_1H | |

Page U14: Nuclear Reaction Types

- | | |
|-----------------------------|-----------------------------|
| 1. beta-negative decay | 7. artificial transmutation |
| 2. alpha decay | 8. fusion |
| 3. artificial transmutation | 9. alpha decay |
| 4. artificial transmutation | 10. beta-negative decay |
| 5. beta-negative decay | 11. fission |
| 6. beta-positive decay | |

Page U17: Radioactive Decay Series for $^{232}_{90}\text{Th}$

1. $^{228}_{88}\text{Ra} \longrightarrow ^{228}_{89}\text{Ac} + ^0_1\beta$ $t_{1/2} = 6.70 \text{ a}$
2. $^{228}_{89}\text{Ac} \longrightarrow ^{228}_{90}\text{Th} + ^0_1\beta$ $t_{1/2} = 6.13 \text{ h}$
3. $^{228}_{90}\text{Th} \longrightarrow ^{224}_{88}\text{Ra} + ^4_2\alpha$ $t_{1/2} = 1.91 \text{ a}$
4. $^{224}_{88}\text{Ra} \longrightarrow ^{220}_{86}\text{Rn} + ^4_2\alpha$ $t_{1/2} = 3.64 \text{ d}$
5. $^{220}_{86}\text{Rn} \longrightarrow ^{216}_{84}\text{Po} + ^4_2\alpha$ $t_{1/2} = 51.5 \text{ s}$
6. $^{216}_{84}\text{Po} \longrightarrow ^{212}_{82}\text{Pb} + ^4_2\alpha$ $t_{1/2} = 0.160 \text{ s}$
7. $^{212}_{82}\text{Pb} \longrightarrow ^{212}_{83}\text{Bi} + ^0_1\beta$ $t_{1/2} = 10.6 \text{ h}$
8. $^{212}_{83}\text{Bi} \longrightarrow ^{208}_{82}\text{Pb} + ^4_2\alpha + ^0_1\beta$ $t_{1/2} = 60.6 \text{ min}$



ALCHEM ELECTIVES TEACHERS' GUIDE

NUCLEAR CHEMISTRY

Page U18: Radioactive Decay

9. most stable - ${}_{90}^{232}\text{Th}$, least stable - ${}_{84}^{216}\text{Po}$
10. ${}_{83}^{212}\text{Bi} \longrightarrow {}_{84}^{212}\text{Po} + {}_{-1}^0\beta$
- ${}_{84}^{212}\text{Po} \longrightarrow {}_{82}^{208}\text{Pb} + {}_2^4\alpha \quad t_{1/2} = 10^{-7}\text{s}$
11. 2.0×10^5 atoms
12. 8.0×10^{19} atoms
13. 0.0200 g
14. 36.2 ug

Pages U23-U24: Nuclear Reactions

Note: Questions 7 to 11 and 27 to 30 inclusive should be assigned after Pages U25 and U26 have been discussed.

- | | |
|---|--|
| 1. ${}_{40}^{97}\text{Zr}$ fission | 11. ${}_{49}^{115}\text{In}$ fusion(proton process) |
| 2. ${}_2^4\alpha$ radioactive decay (alpha and beta-negative decay) | 12. ${}_{93}^{238}\text{Np}$ artificial transmutation |
| 3. ${}_2^4\alpha$ radioactive decay (alpha decay) | 13. ${}_{94}^{239}\text{Pu}$ artificial transmutation |
| 4. ${}_{58}^{147}\text{Ce}$ fission | 14. ${}_0^1\text{n}$ artificial transmutation |
| 5. ${}_{-1}^0\beta$ radioactive decay (beta-negative decay) | 15. ${}_{97}^{245}\text{Bk}$ artificial transmutation |
| 6. ${}_{51}^{139}\text{Sb}$ fission | 16. ${}_0^1\text{n}$ artificial transmutation |
| 7. ${}_{-1}^0\beta$ fusion (proton-proton process) | 17. ${}_0^1\text{n}$ artificial transmutation |
| 8. ${}_6^{12}\text{C}$ fusion (alpha process) | 18. ${}_{100}^{249}\text{Fm}$ artificial transmutation |
| 9. ${}_{48}^{115}\text{Cd}$ fusion(rapid process) | 19. ${}_{101}^{256}\text{Md}$ artificial transmutation |
| 10. ${}_{49}^{115}\text{In}$ radioactive decay(slow process) | 20. ${}_0^1\text{n}$ artificial transmutation |
| | 21. ${}_0^1\text{n}$ artificial transmutation |

22. In nuclear fission a relatively large nucleus absorbs a neutron, becomes unstable and splits into two smaller nuclei. In nuclear fusion two relatively small nuclei unite to form a heavier nucleus.
23. Neutrons, being uncharged, would not be repelled by positively charged nuclei; whereas, positively charged alpha particles would be strongly repelled by nuclei.
24. When a neutron is absorbed by a large nucleus, the nucleus splits into two smaller nuclei plus several neutrons. Some of the neutrons produced may cause additional fission reactions to occur. If only one neutron produced causes a fission of another nucleus then a sustained (constant) fission results. The minimum mass that would permit a constant rate of fission is called the critical mass. If more than one neutron produced causes additional fission reactions, then a chain (explosive) reaction occurs. The minimum mass required for an explosion is called the supercritical mass.
25. The main problems associated with nuclear fusion reactions is that the temperatures required to start fusion reactions are difficult to obtain and the temperatures created by fusion reactions are so high that no known substance could be used to contain the fusion reactions.

26. Nuclear fusion reactions produce more energy per mole of starting material and the fuel is cheap and readily available.
27. proton-proton process
28. alpha process
29. rapid (r), slow (s) and proton (p) processes
30. Iron-56 has the highest nuclear binding energy per nucleon (see Figure U2) and therefore is the most stable isotope. More extreme conditions are required to allow a reaction to occur.

Page U26: - Alpha Process

- | | |
|--------------------------------------|--|
| 1. 2_2^4He | 4. $1_8^{16}\text{O} + 2_2^4\text{He}$ |
| 2. $4_4^8\text{Be} + 2_2^4\text{He}$ | 5. 1_1^1H |
| 3. 1_8^{16}O | |

Page U27: - Fission and Fusion

- | | |
|----------------------------|-----------------------------|
| 1. endothermic fusion B | 3. endothermic fission C |
| 2. exothermic fusion A | 4. exothermic fission D |

Page U29-U30: Energy Changes Associated with Nuclear Reactions

- | | |
|--|--|
| 1. $\Delta H = -5.2 \times 10^8 \text{ kJ}$ | 4. $1.01 \times 10^{10} \text{ kJ}$ |
| 2. $\Delta H = -1.69 \times 10^9 \text{ kJ}$ | 5. $9.00 \times 10^7 \text{ kJ}$ |
| 3. $2.80 \times 10^{10} \text{ kJ}$ | 6. $4.76 \times 10^{10} \text{ kJ}$; $^{56}_{26}\text{Fe}$ has the greater nuclear binding energy per nucleon and is more stable. |

Page U31: Comparison of Energy Changes for Hydrogen

1. $\text{H}_2(\text{s}) + 10^{-2} \text{ kJ} \longrightarrow \text{H}_2(\text{l})$
2. $\text{H}_2(\text{l}) + 10^0 \text{ kJ} \longrightarrow \text{H}_2(\text{g})$
3. $\text{H}_2(\text{g}) + 10^2 \text{ kJ} \longrightarrow \text{H}(\text{g}) + \text{H}(\text{g})$
4. $\text{H}(\text{g}) + 10^3 \text{ kJ} \longrightarrow \text{H}^+(\text{g}) + \text{e}^-$
5. $4_1^1\text{H} \longrightarrow 2_2^4\text{He} + 2_1^0\beta + 10^7 \text{ kJ}$
6. $1_1^1\text{H} + 1_{60}^{144}\text{Nd} + 10^{12} \text{ kJ} \longrightarrow 1_{61}^{145}\text{Pm}$

Page U33: Energy Changes

1. 2.26×10^3 kJ
2. 1.42×10^5 kJ
3. 8.09×10^{10} kJ
4. 7.0×10^{10} kJ

Pages U35-U36: Nuclear Fission Process in Nuclear Power Plants

1. Thermal neutrons are ones that have been slowed down to about 1.0 km/s by collisions with moderator atoms.
2. Moderator is the substance present in nuclear reactors in order to slow down or thermalize the fast neutrons produced during nuclear fission.
3. Deuterium is an isotope of hydrogen containing one proton and one neutron in its nucleus.
4. Control rod is a rod made up of strong neutron absorbers, such as boron, and is used to control the nuclear fission reaction.
5. Heavy water (D_2O) is similar to ordinary water but contains the isotope, deuterium, instead of ordinary hydrogen.
6. The major purpose of a nuclear reactor is to generate electrical energy.
7. Nuclear power is a viable alternative compared to that of using fossil fuels because:
 - a. the cost of both oil and natural gas has been sharply increasing in recent times,
 - b. oil and natural gas supplies are being depleted and there is uncertainty as to availability of future supplies,
 - c. of the shortage of coal supplies in Central and Eastern Canada,
 - d. the sulfur content of coal presents pollution problems.
8. The availability, cost and environmental effects of the traditional sources of electric power (hydro and fossil fuels) will determine which parts of Canada might choose to develop nuclear power plants.
9. Neutrons, originating from the natural fission of U-235, are used as *bullets* in nuclear reactors.
10. Continuous cooling of a nuclear reactor is required to continuously produce electrical power (by thermal generation) and to prevent the melting of reactor components.
11. The neutrons produced in uranium fission must be slowed down or thermalized in order to produce further fissions to sustain the nuclear fission process. Also, U-235, the isotope that undergoes fission, makes up only 0.7 % of naturally occurring uranium.
12. The U.S.A. constructed reactors to run on enriched uranium and use ordinary water as a coolant and moderator. Canada uses natural uranium and heavy water as the coolant and moderator. Heavy water, although not as good a moderator compared to ordinary water, has the advantage of being a much poorer absorber of neutrons. Enriched uranium produces many more neutrons to compensate for the neutrons lost through absorption by the ordinary water.

$$1. \quad M_{H_2O} = 18.0 \text{ g/mol}$$

$$M_{D_2O} = 20.0 \text{ g/mol}$$

$$\frac{M_{D_2O} - M_{H_2O}}{M_{H_2O}} \times 100\% = \frac{2.0 \text{ g/mol}}{18.0 \text{ g/mol}} \times 100\% = 11.1\%$$

$$2. \quad \frac{0.017}{100} = \frac{1.10 \text{ kg}}{x}, \quad x = 6.5 \text{ Mg (6.5t) or 6.5 kL}$$

3. The reaction is endothermic since added heat associated with higher temperatures shifts the equilibrium to the right and the removal of heat associated with lower temperatures shifts the equilibrium to the left; i.e., the reaction would absorb heat going to the right and release heat going to the left.

Pages U46-U47: Nuclear Reactors and the CANDU System

1. Uranium metal is not as stable as the sintered oxide pellets in the high temperature and high neutron bombardment environment in a nuclear reactor.
2. (for diagram see Figure U14) The calandria contains the energy source(uranium oxide fuel bundles) and the coolant:heavy water) used to transfer the heat produced to the power generating portion of a nuclear power plant.
3. The heavy water in the CANDU nuclear reactor serves as the neutron noderator and heat transfer medium.
4. There must be sufficient moderator and sufficient uranium-235 before the nuclear reactor goes critical.
5. The average 2.4 neutrons produced by fission are fast. The nuclear reactor must be designed so that the neutrons are moderated and neutron loss limited so that one neutron per fission survives to fission another U—235 nucleus. This is necessary to maintain a steady chain reaction.
6. The principal way of controlling reaction rate during start up or shut down is by the use of shutoff rods containing strong neutron absorbers such as boron or cadmium.
7. The normal operating control of reaction rate uses compartments capable of being filled with light water and control and adjuster rods similar to shutoff rods. Emergency control of reaction rate may involve, in addition to shutoff rods, the injection of a soluble neutron absorber into the moderator and/or rapid core cooling using light water.
8. The Pu—239 isotope would be present to the greatest extent in uranium spent fuel because of its long half-life.
9. Spent nuclear fuel must be stored in concrete, water-filled bays to allow safe handling and temporary storage of the highly radioactive fission products and by-products.
10. The CANDU reactor uses natural uranium for fuel and heavy water as the coolant and moderator. The LWR reactor uses enriched uranium and ordinary water. Natural uranium produces fewer neutrons per unit mass of fuel. However, the use of heavy water, which is a poor neutron absorber compared to ordinary water, results in a more efficient use of neutrons to promote furtherw fussion reaction(i.e., less neutron loss to the moderator/coolant).

11. The CANDU nuclear reactor design of having the coolant circulating the fuel bundles under pressure in individual fuel channels gives it advantages over other reactors.
12. Heavy water is expensive to produce (\$234/kg in 1978) and adds appreciably to the capital cost of a nuclear reactor. The production of radioactive tritium oxide (${}^3_1\text{H}_2\text{O}$) may pose safety hazards in the event of spills or serious accidents.
13. Spent fuel may, in the future, be reprocessed to provide additional fuel. The safety and security of stored spent fuel is a major problem regarding public acceptance of nuclear energy.

Pages U55-U56: Applications of Nuclear Reactors

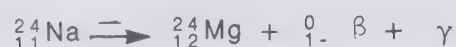
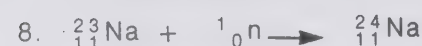
1. Nuclear reactors produce heat energy, are used as instruments for research, produce radioisotopes for industrial, agricultural and medical application and produce nuclear fuels from nonfissionable elements.

2. (See Page U50)



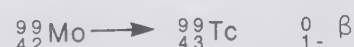
6. (See Page U51)

7. (See Page U52)



The gamma radiation may be detected by a gamma ray scanner when sodium—24 is used as a tracer.

9. Radioisotope tracers are used for diagnosis. In diagnosis, a specific radioisotope is ingested, then a scanner or camera produces an image of the emission from the affected area. Radioisotope emissions are used to destroy diseased or malignant cells in radiation therapy.
10. Isotope with short half-lives are used so that after a localized area is irradiated, the isotope loses its activity rapidly enough to present little hazard by the time it is released to the blood stream.



(These are overall reactions.
In each case there are two
short-lived intermediates.)



13. Each fission of a uranium—235 nucleus produces an average of 2.4 neutrons; however, only one neutron is required to maintain the chain reaction. The surplus neutrons may be captured by nonfissile material (e.g., U—238) to produce a fissionable product (e.g., Pu—239). More fissionable material can be produced than is consumed because the number of surplus neutrons exceeds the minimum number of neutrons required to maintain the chain reaction.

	Name	Isotope Notation	Atomic Number	Mass Number	Subatomic Particles			Net Charge On Species
					Protons	Neutrons	Electrons	
1.			27	58	27	31	27	0
2.		$^{60}_{27}\text{Co}$	27		27	33	27	0
3.		$^{127}_{53}\text{I}^-$	53		53	74	54	1-
4.		$^{131}_{53}\text{I}^-$	53	131	53		54	1-
5.	thorium		90	234	90	144	90	0
6.		$^{239}_{94}\text{Pu}$	94	239	90		90	0
7.	phosphorus	$^{32}_{15}\text{P}$	15		15	17	15	0
8.	sodium ion	$^{24}_{11}\text{Na}^+$	11	24	11			

9. Resulting nuclei has atomic number less by 2 and mass number less by 4.
10. Resulting nuclei has atomic number greater by 1 and mass number unchanged.
11. Resulting nuclei has atomic number less by 1 and mass number unchanged.
12. Resulting nuclei has the same atomic number and the same mass number.
13. Nuclear binding energy, the ratio of neutrons to protons and the odd-even nature of the number of neutrons and protons.
14. The most stable nuclei are those with certain neutron-proton combinations.
15. $^{238}_{92}\text{U}$ is likely to be more stable because it has an even number of neutrons compared to $^{235}_{92}\text{U}$ which has an odd number of neutrons.
16. β^- emission
17. β^+ emission(positron emission)
18. $^{22}_{11}\text{Na} \longrightarrow ^{22}_{10}\text{Ne} + ^0_{+1}\text{e}$
19. $^{214}_{83}\text{Bi} \longrightarrow ^{214}_{84}\text{Po} + ^0_{-1}\text{e}$
20. $^{226}_{88}\text{Ra} \longrightarrow ^{222}_{86}\text{Rn} + ^4_2\text{He}$
21. $^{95}_{38}\text{Sr}$
22. $^{139}_{56}\text{Ba}$
23. $^{131}_{50}\text{Sn}$
24. ^4_0n
25. 1989(10.54a)
26. $1.73 \times 10^4 \text{ a}$

27. Nuclei undergoing fission split into two smaller nuclei of approximately similar mass. Nuclei undergoing fusion unite to form heavier nuclei.
28. More massive nuclei like ${}^{235}_{92}\text{U}$ are more likely to undergo fission whereas low mass nuclei like ${}^2_1\text{H}$ are more likely to undergo fusion.
29. For exothermic nuclear fission or fusion reactions, the binding energy per nucleon increases from the reactant(s) to the products. For endothermic reactions, the binding energy will decrease in both fission and fusion reactions.
30. $8.90 \times 10^9 \text{ kJ}$

31. $-4.81 \times 10^8 \text{ kJ}$

32. The exchange of *deuterium* between water and hydrogen sulfide at different temperatures. The process may be expressed by the following equilibrium equation.

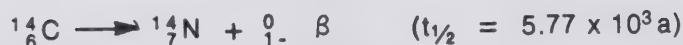
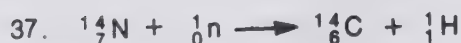
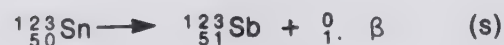
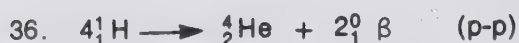


At high temperatures equilibrium to the right is favored and at low temperatures equilibrium to the left is favored.

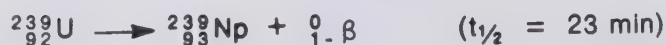
33. The CANDU reactor uses natural uranium oxide fuel. The uranium oxide is pressed into pellets, sintered and ground. These pellets are placed inside zircalloy tubes to form fuel rods which are assembled to form single fuel bundles. The fuel bundles are then inserted into pressure tubes located in a large tank or calandria.

34. (See Figure U14, Page U41)

35. The unique feature of the CANDU nuclear reactor is the use of heavy water as both coolant and moderator. The low neutron absorbing properties of the heavy water moderator allows the system to utilize natural uranium oxide as fuel.



Living material constantly exchanges carbon with the environment. Therefore, the relative amount of CARBON—14 remains constant in the organism. Upon death, this exchange stops and the carbon—14 present decays without being replenished. Since carbon—12 is stable, the carbon—14 to carbon—12 ratio decreases with time.



OD 41 A3314 1977 TCH-GD- C-3
ALBERTA CHEMISTRY PROJECT
MATERIALS

ALCHEM ELECTIVES/
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RECOMMENDED FOR USE
IN ALBERTA SCHOOLS

EDUC	AP 10 '83
RETURN	APR 12 '83
EDUC	MAR 17 '88
MAR 18	RETURN
	DEC 10 '91
DEC 02	1991 RETURN

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Alberta Chemistry Project
Materials.

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